Cat. No. 88F0006XIE01011

Practices and Activities of Canadian Biotechnology Firms: Results from the Biotechnology Use and Development Survey - 1999

Statistics Canada Statistique Canada

Canada

Practices & Activities of Canadian Biotechnology Firms: Results from the Biotechnology Use & Development Survey - 1999

Chuck McNiven
Science, Innovation and Electronic Information Division

August 2001

88F0006XIE No. 11

ST-01-11

106-00150/

CONTACTS FOR MORE INFORMATION

Science, Innovation and Electronic Information Division

Director Dr. F.D. Gault (613-951-2198)

Assistant Director Brian Nemes (613-951-2530)
Assistant Director Paul McPhie (613-951-9038)

The Science and Innovation Information Program

Chief, Indicators Development
Dr. Frances Anderson (613-951-6307)

Chief, Knowledge Indicators
Michael Bordt (613-951-8585)

Chief, Innovation
Daood Hamdani (613-951-3490)

Chief, Life Science Unit
Antoine Rose (613-951-9919)

Science and Innovation Surveys Section

Chief
Bert Plaus (613-951-6347)

Senior Project Officer
Janet Thompson (613-951-2580)

FAX: (613-951-9920)

Working Papers

The Working Papers publish research related to science and technology issues. All papers are subject to internal review. The views expressed in the articles are those of the authors and do not necessarily reflect the views of Statistics Canada.

The Science and Innovation Information Program

The purpose of this program is to develop **useful indicators of science and technology activity** in Canada based on a framework that ties them together into a coherent picture. To achieve the purpose, statistical indicators are being developed in five key entities:

- **Actors**: are persons and institutions engaged in S&T activities. Measures include distinguishing R&D performers, identifying universities that license their technologies, and determining the field of study of graduates.
- **Activities**: include the creation, transmission or use of S&T knowledge including research and development, innovation, and use of technologies.
- **Linkages**: are the means by which S&T knowledge is transferred among actors. Measures include the flow of graduates to industries, the licensing of a university's technology to a company, co-authorship of scientific papers, the source of ideas for innovation in industry.
- **Outcomes**: are the medium-term consequences of activities. An outcome of an innovation in a firm may be more highly skilled jobs. An outcome of a firm adopting a new technology may be a greater market share for that firm.
- **Impacts**: are the longer-term consequences of activities, linkages and outcomes. Wireless telephony is the result of many activities, linkages and outcomes. It has wide-ranging economic and social impacts such as increased connectedness.

The development of these indicators and their further elaboration is being done at Statistics Canada, in collaboration with other government departments and agencies, and a network of contractors.

Prior to the start of this work, the ongoing measurements of S&T activities were limited to the investment of money and human resources in research and development (R&D). For governments, there were also measures of related scientific activity (RSA) such as surveys and routine testing. These measures presented a limited picture of science and technology in Canada. More measures were needed to improve the picture.
Innovation makes firms competitive and we are continuing with our efforts to understand the characteristics of innovative and non-innovative firms, especially in the service sector that dominates the Canadian Economy. The capacity to innovate resides in people and measures are being developed of the characteristics of people in those industries that lead science and technology activity. In these same industries, measures are being made of the creation and the loss of jobs as part of understanding the impact of technological change.

The federal government is a principal player in science and technology in which it invests over five billion dollars each year. In the past, it has been possible to say only *how much* the federal government spends and *where* it spends it. Our report **Federal Scientific Activities, 1998 (Cat. No. 88-204)** first published socio-economic objectives indicators to show *what* the S&T money is spent on. As well as offering a basis for a public debate on the priorities of government spending, all of this information has been used to provide a context for performance reports of individual departments and agencies.
As of April 1999, the Program has been established as a part of Statistics Canada's Science, Innovation and Electronic Information Division.

The final version of the framework that guides the future elaboration of indicators was published in December, 1998 (**Science and Technology Activities and Impacts: A Framework for a Statistical Information System,** Cat. No. 88-522). The framework has given rise to **A Five-Year Strategic Plan for the Development of an Information System for Science and Technology** (Cat. No. 88-523).

It is now possible to report on the Canadian system on science and technology and show the role of the federal government in that system.

Our working papers and research papers are available at no cost on the Statistics Canada Internet site at http://www.statcan.ca/cgi-bin/downpub/research.cgi?subject=193.

Acknowledgements

Several departments and agencies provided important inputs at various stages of the survey. They were Industry Canada, the Canadian Biotechnology Secretariat, Department of Foreign Affairs and International Trade, Agriculture Canada, the National Research Council, Canadian Institute for Health Research, Natural Resources Canada, Health Canada and Environment Canada. Funding was provided by the Canadian Biotechnology Strategy.

The survey also owes a debt of gratitude to the firms, that must remain anonymous, who gave their time and ideas in development and testing of the survey and as well as those firms that responded to the survey.

At Statistics Canada numerous people contributed to the survey, among those are Antoine Rose, Claire Racine-Lebel, Craig Byrd, Annie Gilbert and the methodology team of Lyne Guertin, Richard Laroche, Nicolas Lavigne and Yves Morin.

ELECTRONIC PUBLICATIONS AVAILABLE AT
www.statcan.ca

Introduction

Canada had 358 biotechnology firms[1] in 1999 generating revenues of more than $1.9 billion from activities directly related to biotechnology, according to data from the Biotechnology Use and Development Survey -1999. The survey, administered by the Science, Innovation and Electronic Information Division of Statistics Canada, provides information on companies involved in developing new products and processes using biotechnologies and was conducted as part of a project to develop biotechnology statistics as part of the Canadian Biotechnology Strategy. It addressed the questions: What are the characteristics and activities of firms that use or develop biotechnology as an important part of their firms' activities?

This paper, the second in a series based on the survey, continues to address those questions with a summary of the strategies and business practices firms used, and information on the business environment faced by biotechnology firms. These issues considered in conjunction with information[2] on revenue, research and development, import and export, product pipeline and human resources characteristics of biotechnology firms contribute to a more comprehensive portrait of the biotechnology sector in Canada.

Canadian biotechnology firms demonstrated growth in activities including revenues, research and development, and imports and exports. Revenues for 1999, a 25% increase over 1998 revenues, are expected by the firms to more than double to $5 billion by 2002. Biotechnology firms are active in exporting biotechnology, with the value of biotechnology firms' biotechnology exports exceeding $700 million in 1999, growing to almost $1.7 billion in 2002. Firms were actively involved in the development of new biotechnology products or processes with about one-half of the over 17,000 products or processes currently in development at the research and development stage.

This paper contributes to the understanding of biotechnology firms by looking at how firms achieved this growth. Underlying these financial facts are the strategies and activities of biotechnology firms. Some of the topics this paper examines are

- Biotechnologies used and purpose of use
- Human resources and recruiting practices
- Collaborative arrangements, spin-offs, contracting of activities
- Intellectual property and patents
- Benefits from biotechnologies
- Barriers to commercialising biotechnologies
- Source and destination of import and exports

---

[1] Biotechnology firms are defined as those firms conducting active research and development in biotechnology and consider biotechnology central to their activities. This group completed the entire survey with the exception of question 2.

[2] See the working paper Biotechnology Use & Development-1999, Statistics Canada, March 2001. Available for download at http://www.statcan.ca

Table 1
Selected Characteristics of Core Biotechnology Firms

	1999				
	Number of Firms	Biotechnology Revenues ($000,000)	Biotechnology R&D Spending ($000,000)	Biotechnology Exports($000,000)	Biotechnology Employees
British Columbia	71	138	131	60	1,191
Alberta	28	90	31	15	577
Saskatchewan	16	433	28	208	291
Manitoba	6	69	20	43	357
Ontario	111	635	223	164	2,561
Quebec	107	554	337	227	2,588
Nova Scotia	7	2	4	..	77
Maritimes	19	28	6	..	183
Canada	358	1,948	827	718	7,748

Source: Statistics Canada

*: Please use with caution, unreliable due to high coefficient of variation

Maritimes includes NS, PEI, NB & Nfld.

Revised Figures

.. Data not available

Background

The use of biotechnology in human activity is not new. Classical forms of biotechnologies such as fermentation have been a part of industrial processes for decades, if not centuries. But today, more recent developments in biotechnologies are diffusing throughout the economy. Industrial, health and environmental activities are being transformed and new ones are emerging. Traditional biological processes continue today but are enhanced by scientific processes intended to not only understand organisms but to decode and modify organisms and at times contributing to new products or processes. The Canadian Biotechnology Advisory Committee[3] (CBAC) described "biotechnology as a body of technical knowledge about living organisms or their constituent parts and applied biotechnology as those aspects of biotechnology that are used to make products and drive processes that serve social, scientific or economic purposes."

This survey is the latest in a series of initiatives intended to develop a biotechnology statistics program. Statistics Canada administered two previous surveys dedicated to biotechnologies. The first, the Biotechnology Use Survey – 1996[4] examined the use of biotechnologies in selected Canadian industries. The second, the Biotechnology Firm Survey - 1997 was aimed at those firms actively conducting research and development and considered to be the core biotechnology firms.

The Biotechnology Use and Development Survey – 1999 combines elements and the legacy of those surveys in order to provide a comprehensive set of statistics. It addresses questions such as who is using biotechnologies and why they are using biotechnologies, who develops biotechnologies and what is being developed. This survey in conjunction with studies examining the supply and demand of capital, as well the growth of

[3] See Canadian Biotechnology Advisory Committee Annual Report 1999-2000

[4] See Antoine Rose *Biotechnology Use by Canadian Industry – 1996*, Statistics Canada for complete details

biotechnology firms contributes to the complete portrait of Canada's biotechnology sector.

The purpose of the survey was to provide an accurate statistical portrait of biotechnology in Canada from three perspectives and these perspectives provide the outline for this paper, a previous paper and forth-coming papers. Three groups are discussed: core biotechnology firms, users of biotechnology and non-users of biotechnology.

The first paper examined financial aspects of biotechnology firms. This paper, through the use of data tables and accompanying text, gives an overview of the business strategies and practices of biotechnology firms. These firms conduct an active research and development program in biotechnology and consider biotechnology central to their activities by using biotechnology to develop new knowledge, products and processes.

The final paper will discuss data on the firms that use biotechnology in their day-to-day operations, but do not develop new products or processes. They use biotechnology as they would use any other factor of production. Biotechnologies are simply an expedient way of conducting business. The paper will include information on the final group, non-users of biotechnologies. These firms provided information on why they did not use biotechnologies.

Current Use of Biotechnologies

Firms provided information on their current use of biotechnologies, the purpose of using biotechnology, number of years using the biotechnology, and, if they were not using a particular biotechnology[5], if they planned to use that biotechnology within 3 years. This section discusses those results for the core biotechnology firms, by focusing on the four major categories; DNA based, Biochemistry/Immunochemistry, Bioprocessing based and Environment biotechnologies. The 'other' category requires additional examination prior to reporting. These four sections are made up of 17 different biotechnologies ranging in use by 18 firms employing Bioleaching/Biopulping/Biobleaching/Biodesulphurization to 204 firms using Extraction/Purification/Separation. Average time of use of biotechnologies ranges from 3 years to almost 11 years. Research and development is the most common use, not surprising given the fact the majority of respondents are R&D intensive firms.

There were a total of 423 instances of firms[6] using DNA based biotechnologies, with research and development (R&D) emerging as the primary use, reported in 416 cases. This far outstripped their use in current production. Perhaps not surprising data is not published for DNA based biotechnologies used for environmental purposes due to low level of use. With an average use of 4 years, DNA based biotechnologies is the youngest of the different sectors. It includes bioinformatics used for an average of 3 years by the 83 firms reporting its use, almost entirely for R&D purposes. This was the lowest average

[5] See Question 1, page 2 of the questionnaire found in Appendix 1

[6] Firms provided multiple responses to biotechnologies used. These are the results for the 358 core biotech firms.

time of use of any biotechnology. Genetic engineering/DNA sequencing/synthesis/amplification sub-grouping was the most popular biotechnology with 140 firms reporting its use primarily for R&D. Growth in the use of these biotechnologies is anticipated[7], with 151 new users of DNA based biotechnologies expected within the next 3 years.

The eight biotechnologies found in biochemistry/immunochemistry section were the most frequently biotechnologies with a cumulative 795 occurrences, mainly for R&D purposes (700), but also for production (243) and environmental (78) purposes. Average time of use had the greatest range from 4.2 years to 10.6 years. The microbiology/virology/microbial/ecology sub-group was reported as currently used by 171 firms for R&D, production and environmental purposes averaging 10.6 years in use. This was one of the longest average periods a biotechnology was used.

Bioprocessing based biotechnologies have been used for the longest period with an average period of 8.5 years. As well it has the highest number of firms using it in current production. This may reflect its maturity, and it may have, as a group, shifted from a research and development focus to a more standardized process. Only 35 more firms plan to introduce these technologies in the next 3 years. The final group is the environmental biotechnologies, where again the focus is on R&D, but with a significant number of firms reporting using these techniques in current production stage. Only 10 firms plan to introduce environmental biotechnologies to their operations before 2002.

[7] Note To Readers: Projections for future use of biotechnologies and other forecasts used in later sections of this paper were provided by respondents and are not forecasts created by Statistics Canada.

Table 2
Number of Biotechnologies Used by Canadian Firms - 1999

Biotechnologies	Currently Used in Operations	Current Use of Biotechnology: Product/Process R&D	Current Use of Biotechnology: Current Production	Current Use of Biotechnology: Environmental Purposes	Number of Years in Use	Plan to Use in Next 3 Yrs
	Number of Firms					
DNA Based						
Gene Probes/DNA Markers	130	127	25		4.8	34
Bio-informatics	83	83	9		3	35
Genomics/Pharmacogenetics	70	70	7		3.5	48
Genetic Engineering/DNA Sequencing/Synthesis/Amplification	140	136	31		4.6	34
Any DNA Based	423	416	72		4	151
Biochemistry/Immunochemistry						
Vaccines/Immune Stimulants	83	83	29	7	8.7	23
Drug Design/Delivery	102	100	25		6	20
Diagnostic Tests/Antibodies	138	122	52	12	6.6	15
Peptide/Protein Sequencing/Synthesis	103	94	21		4.5	34
Cell Receptors/Signaling/Pheromones/Structural Biology	82	79	6		4.2	28
Combinatorial Chemistry/3D molecular Modeling	54	54	6		4.8	43
Biomaterials	62	44	31	11	6.1	
Microbiology/Virology/Microbial Ecology	171	145	73	42	10.6	
Any Biochemistry/Immunochemistry	795	700	243	78	6.4	185
Bioprocessing Based						
Cell/Tissue/Embryo Culture Manipulation	163	151	54	8*	6.7	3*
Extraction/Purification/Separation	204	177	101	19	8.2	14
Fermentation/Bioprocessing/Biotransformation/Natural Products Chemistry	180	141	98	38	10.6	21
Any Bioprocessing Based	547	469	254	57	8.5	35
Environment						
Bioleaching/Biopulping/Biobleaching/Biotreatment	18	15	9	4*	5.7	3*
Bioremediation/Biofiltration/Phytoremediation	46	36	15	36	8.9	7
Any Environment	64	51	24	40	7.3	10
Other	24	14	20		9.1	

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999
Preliminary Data
.. Figures not available
* Use with caution, unreliable due to high coefficient of variation

Benefits of Using Biotechnology

According to 96% of the respondents, biotechnology is used first to develop new products or processes. However firms reported a wide range of benefits derived from using biotechnologies. Developing new products or processes was cited by 96% of the respondents as an important (21%) or highly important (75%) benefit to their firm. Further, 90% of the respondents reported that improvement in product quality was important or highly important. Lower capital cost was rated with low importance as a benefit by over a quarter of the respondents. Generally product improvement related benefits were rated as important benefits of using biotechnology while reduced costs were of low importance as benefits. Improving market position was also rated highly by firms as an important benefit for using biotechnologies.

Table 3
Benefits of Using Biotechnology

	1999					
	N/A	Low Importance		Neutral		High Importance
		(1)	(2)	(3)	(4)	(5)
Lower Labor Costs	119	36	18	38	14	25
Lower Capital Costs	12	39	13	34	15	29
Lower Energy Costs	125	41	11	42	11*	19
Develop New Products or Processes	10	0	0	20*	48	171
Extend Product Range	26*	15*	8	22	42	135
Improvement in Product Quality	20	..	..	22*	51	140
Increase Production Flexibility	124	17	4	37	41	27
Lower Maintenance Expenses	124	33	23	43	10	16
Cleaner Production/Pollution Reduction	113	21	13	32	34	37
Improve Market Position	41	..	..	9	76	116
Increase Sales	73	11*	..	22	48	95
Reduce Time to Market/Faster Delivery	105	9	5	15	41	75
Other	242	0	0	0	0	8

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available, suppressed due to very high coefficient of variation

* Use with caution, unreliable due to high coefficient of variation

Information Sources On Biotechnology

As the technology is relatively new, firms must seek and exchange information. Firms used a wide variety of sources to obtain information on biotechnology. Among the most highly rated were Universities/Colleges and personal contact as well as conferences and workshops. These latter 2 highlight the continued importance of tacit knowledge that can often times be exchanged only through personal contact. Despite this, 98% of the firms used the Internet, for such diverse purposes as accessing databases and information sources (85%) to marketing and selling purposes (53%) to sharing R&D (44%). Interesting to note is less than 20% of respondents relied on the Internet for e-commerce purposes. Firms were least likely to use government sources as information sources on biotechnology.

Through-out this paper firms are referred to as small medium or large firms. These size groups are defined as: small firms have 50 or less employees, medium firms have 51-150 employees and large firms have 151 or more employees.

Table 4
Sources of Information On Biotechnology

	1999					
	N/A	Low Importance		Neutral		High Importance
	0	(1)	(2)	(3)	(4)	(5)
Internal Resources/Staff or Parent /Subsidiary Firm	52*	8	12	51	75	161
Academic Journals/Trade Publications	..	..	16	89	85	160
Universities/Colleges/Private Training Institutions	8*	14	31	102	103	99
Federal Government Department/Agency	14	81	65	85	65	47
Personal Contact With Others (Tacit Knowledge)	10*	..	14*	83	127	122
Other Companies	7	40	57	103	77	74
Provincial Government Department/Agency	16	138	73	67	36	27*
Professional/Industry Associations	8*	64	85	108	45	47
Library/Literature Searches	..	35*	24	57	89	149
Database Retrieval Services	9*	70	55	65	50	109
Conferences/Workshops/Trade Shows	0	31*	22	88	130	87
Other	342	..	..	..	..	2

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available, suppressed due to very high coefficient of variation

* Use with caution, unreliable due to high coefficient of variation

Table 5
Internet Use by Purpose

1999

Internet Use by Firm Size

	Sharing R&D	Marketing/ Selling	Purchasing Goods and Services	Accessing Databases/ Information Sources	e-Commerce	Human Resources Search	Public Relations	General Communication	Other	Total Unique Firms
Small	114	132	95	225	43	92	105	..	..	265
Medium	15	38	20	45	8	20*	19	..	..	48
Large	24	15	23	28	9	21	27	..	..	37
Total	153	185	138	299	59	133	151	..	..	350

Internet Use By Sector

	Sharing R&D	Marketing/ Selling	Purchasing Goods and Services	Accessing Databases/ Information Sources	e-Commerce	Human Resources Search	Public Relations	General Communication	Other
Human Health	71	67	64	130	21	84	80	..	..
Agriculture	35	40	16	69	12	18	30	..	..
Natural Resources	10	9	8	10	..	4*	9	..	..
Environment	7	23*	..	33	..	..	3	..	..
Aquaculture	6*	6*	7*	10	..	..	7	..	..
Bioinformatics	10	11	10	17	8	12	7	..	..
Food	8	23	20	20	10*	4	..	..	..
Other	6	5	..	9	..	..	..	..	..
Total	153	185	138	299	59	133	151	..	..

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Obstacles to Biotechnology Commercialization

As firms race to commercialize products they face a myriad of obstacles ranging from the regulatory system to financial concerns and marketing issues. Access to capital[8] and time/cost constraints were seen as the most significant obstacles to the commercialization of biotechnology. Patent protection issues were rated as not significant impediments to commercialization by at least 62% of respondents, but patent rights held by others was rated as an important obstacle by over 30% of respondents. Interestingly public perception of biotechnology was given low importance by over a third of respondent and not applicable by a further 23% of respondents. For marketing issues, respondents provided a diverse range of opinions with no outstanding observations present.

Table 6
Obstacles to Biotechnology Commercialization (Number of Firms)

1999						
	Importance					
	Low				High	
Obstacles	**1**	**2**	**3**	**4**	**5**	**N/A**
Access to Capital	25	19	38	87	145	43
Access to Technology/Information	60	76	86	43	41	53
Access to Human Resources	55	62	62	63	63	53
Domestic Market Too Small	40	54	35	58	80	91
Lack of Access to International Markets	62	74	62	38	41	82
Transport Regulations on Biotech	90	51	43	19	20	135
Lack of Distribution & Marketing Channels	65	48	53	53	26	113
Public Perception/Acceptance	93	43	68	33	38	83
Regulatory Requirements	37	30	85	67	89	51
Time/Cost	20	26	55	109	124	24
Patent Rights Held by Others	63	46	43	49	63	96
Lack of Patent Protection for Plants	62	24	20	14	15	223
Lack of Patent Protection for Animals	57	27	7	13	13	241
Lack of Patent Protection for Human Components (e.g. organs, tissue)	56	25	7	7	8	255

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Business Relationships

During the development of products involving biotechnology, firms face multiple challenges. Each of these challenges requires specific competencies/capacities that may or may not exist within the firm. One option is to form alliances with others. The type of partner or style of partnership will vary with the particular challenge faced. For example in the early stages of product development firms seeks more technical help though alliances with universities or research facilities. At a different stage of development gaining regulatory approval requires extensive specialized knowledge and funding. At the commercialization stage firms may be looking for distribution channels. These various challenges mean different types of partners and partnerships.

[8] See section on raising capital for additional details

This section presents and discusses the data as it relates to the methods firms use to interact with each other. This includes collaborative arrangements (their purpose and the type of partner), intellectual property arrangements, spin-offs and contracting out arrangements.

The term collaborative/co-operative arrangement or alliance describes a set of business process involving some form of defined partnering between enterprises or businesses. In generic terms alliances are formal or informal arrangements between two or more enterprises to achieve specific goals. Alliances range from permanent agreements to carry on business to formal financial agreements and exchanges, to informal exchange arrangements of knowledge, technology or equipment sharing. Interest in collaborative arrangements was generated in part by results from the *Biotechnology Firm Survey - 1997* (Statistics Canada). Close to 58% of responding firms entered into at least one strategic alliance and 67% were involved in a research and development partnership[9].

In the biotechnology survey the term collaborative/co-operative arrangement was defined as "...the active participation in projects by your company and other companies or organizations in order to develop and/or continue work on new or significantly improved biotechnology processes, products and/or services. Pure contracting out is not regarded as collaboration." The survey sought information on the number of collaborative arrangements, the purposes underlying collaborative arrangements, the type and location of partners and finally on spin-offs. Data on these topics follow a discussion on collaborative/co-operative arrangements from various perspectives.

An alliance is a relationship between two or more entities; large or small, domestic or foreign, with shared goals and economic interests and may be vertical or horizontal. The terms or labels may vary but strategic alliances are a function of the content of the relationship. The delimiting parameters of the relationship could include time, money, knowledge, product development, market penetration, and geographic characteristics, singly or in combination making the strategic alliance a flexible business relationship particularly suitable for enterprises with different capabilities.

Some suggest that a significant aspect of alliances in biotechnology is the role of the regulatory process in testing and introducing products to market. This regulatory process requires considerable time, resources, and expertise to navigate and in itself may be a pre-condition for the formation of an alliance. For example the United States Office of Technology Assessment estimates that it takes 7-12 years and US$200 - US$350 million to develop and then take a single human health biotechnology product to the end of the regulatory approval process. Evidence from the survey shows among biotech firms in the 1999 survey 6% of collaborative arrangements were for the purpose of regulatory affairs.

[9] Survey details available on request from the Science, Innovation & Electronic Information Division.

Motives for entering a co-operative relationships are multiple and varied. Common motives include access to R&D capabilities or to generate more rapid innovation through creative synergies, to gain marketing or production expertise, access to new markets, or generating capital. Sharing and advancement of research can be attractive to under-capitalized firms or firms lacking resources to obtain sophisticated equipment and personnel. Firms may seek an alliance for R&D as a method to reduce risk associated with efforts to solve problems or to further advance innovation. In this case the biotech firms entered into collaborative arrangements with the purpose of research and development 33% of the time. This was the number one reason firms entered collaborative arrangements.

Alliances often occur in young industries where speed and flexibility are key components to survival. This may be especially true in the biotechnology industry where firms race to patent innovations (Baum & Silverman). In Canada 9% of the arrangements were sought to protect intellectual property and 6% for regulatory affairs.

Lerner (1998) found that in the United States large pharmaceutical or medical firms ally with small biotech firms lacking complementary assets such as sales forces and manufacturing, but rich in innovative ideas or research. Larger firms benefit from smaller firm's innovation speed and freedom, and the smaller firms benefit from the larger firm's infrastructure. Lerner (1997) asserts young firms "lack the financial resources to effectively introduce a new product" and "lack complementary assets (i.e. sales forces and manufacturing know-how). As a result, strategic alliances between small, research-intensive firms and larger corporations have become common-place" (p1). Results from the survey show that small firms allied with large firms 31% of the time.

Participants in alliances come from business, academia and government sectors in almost any combination. Relationships can be vertical, between vendor and customer, or horizontal, between vendors, local or global and occur between competitors. Firms reached 194 agreements with universities/hospitals, 107 agreements with government departments/agencies and 336 collaborative arrangements with other business both smaller and larger.

Hagedoorn (p208) defines alliances as "inter-firm agreements that can reasonably be assumed to affect the long-term product market positioning of at least one partner". Gimba (1994) sees strategic alliances as transition mechanisms that allow members to pool their resources in the same country as well as across international borders. An important note is that numerous articles on strategic alliances allude to the international component of strategic alliances as source and destination. Niosi (1996, p109) suggests that two prime methods exist for firms to enter into alliances; memorandums of understanding (MOU) linking firms for a project bound by specified parameters and joint ventures.

Baldwin (1997b) identifies two methods of research and development involving a strategic arrangement with another entity. Collaborative research "involves a partnership and, therefore, extends the boundary of the firm" and "is a substitute for contract research where third-party or market transactions do not work as well as internalization via the creation of a new entity". Contract research: "allows a firm to incorporate new ideas when it does not have external expertise. It works particularly well when the incorporation of new ideas and products does not involve tacit or firm specific knowledge" (ibid). This type of alliance is market based.

Biotechnology firms were very active in their contracting out activities. Firms contracted out almost $1 billion for a variety of purposes. By far the most common purpose was (187 firms) contracts valued at $858 million for research and development purposes. This exceeds the value firms spent on research and development. Firms (85) contracted over $100 million for regulatory and clinical affairs and lesser amounts for marketing and management purposes. Firms in Quebec were the most active in contracting activity, for example, contracting over 70% of the research and development contracts. The human health sector contracted almost $400 million in research and development contracts and 98% of the regulatory and clinical affairs contracts.

Niosi (2000) states that "Alliances are key for emerging firms that need enormous resources – knowledge, facilities, skilled personnel and capital. It is no surprise then that three quarters of the companies (47/60 or 78 percent) conducted alliances" (p.16). Alliances are not only established between firms. Niosi (2000) found that two-thirds of firms conducting alliances had university partners, mainly aimed at basic research (p.16).

Table 7

Total Values of Biotechnology Related Contracts ($000,000) by Size

	1999			
	Purpose of Contract			
	Research & Development	Regulatory/ Clinical Affairs	Marketing/ Distribution	Management/ Licensing
Small	372	69	8	3
Medium	..	20	..	..
Large	..	15	..	..
Canada	859	103	14	8

Total Values of Biotechnology Related Contracts ($000,000) by Province

	1999			
	Purpose of Contract			
	Research & Development	Regulatory/ Clinical Affairs	Marketing/ Distribution	Management/ Licensing
British Columbia	18	18	1	5*
Alberta	9	7	.5*	..
Saskatchewan	1	..	.4*	..
Manitoba	2	..	..	..
Ontario	215	73	8*	..
Quebec	613	6	5	1
Nova Scotia	..	..	..	..
Maritimes	..	..	..	..
Canada	859	103	14	8

Total Values of Biotechnology Related Contracts ($000,000) by Sector

	1999			
	Purpose of Contract			
	Research & Development	Regulatory/ Clinical Affairs	Marketing/ Distribution	Management/ Licensing
Human Health	386	101	9	6*
Agriculture	8	..	1	..
Natural Resources	1*	..	..	..
Environment	..	..	..	..
Aquaculture	..	..	..	..
Bio Informatics	5*	..	2	1
Food Processing	..	..	..	..
Other	0	..	..	..
Canada	859	103	14	8

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Note: Due to rounding, components may not add to totals

Table 8

Number of Firms Contracting Out Biotechnology Activities by Size

	1999			
	Purpose of Contract			
	Research & Development	Regulatory/ Clinical Affairs	Marketing/ Distribution	Management/ Licensing
Small	128	71	36	45
Medium	36	7	..	..
Large	23	6	..	..
Total	187	85	42	49

Number of Firms Contracting Out Biotechnology Activities by Province

	1999			
	Purpose of Contract			
	Research & Development	Regulatory/ Clinical Affairs	Marketing/ Distribution	Management/ Licensing
British Columbia	30	19	13	10
Alberta	14	7	4	..
Saskatchewan	4*	..	4	..
Manitoba	4	..	..	..
Ontario	66	33*	5	..
Quebec	67	20	16	14
Nova Scotia	..	..	..	..
Maritimes	..	..	..	..
Canada	187	85	42	49

Number of Firms Contracting Out Biotechnology Activities by Sector

	1999			
	Purpose of Contract			
	Research & Development	Regulatory/ Clinical Affairs	Marketing/ Distribution	Management/ Licensing
Human Health	80	49	21	21
Agriculture	56	..	8	..
Natural Resources	6	..	..	..
Environment	..	..	..	..
Aquaculture	..	..	..	..
Bio Informatics	9	3*	5	5
Food Processing	10	..	..	..
Other	..	3*	..	3*
Total	187	85	42	49

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Roja (1996) theorizes that alliances serve as a method for larger firms to secure rights to technology by establishing market, research or manufacturing relationships with smaller firms. The smaller firm benefits from access to cash, business expertise, complementary technologies, or the ability to combine marketing, distribution, manufacturing or financing opportunities. Not to be overlooked is the credibility given to a smaller firm when allied with a larger firm. This view is echoed by Senker & Sharp[10] (1997) who further the idea with the opinion that the smaller dedicated biotechnology firm requires a relationship with a larger firm in order to attract venture capital funds. Small biotechnology firms entered into collaborative arrangements to conduct R&D (33% of arrangements for small firms), access knowledge (20%) and prototype development (17%). Data for access to capital was too small to disclose.

Madhavan et al (1998) reason that alliances not only serve the traditional practices and needs of business but serve as the channels in which information and knowledge are transferred. The alliances form part of the network of relationships in business. This appears to be the case based on evidence from the survey; biotechnology firms entered into a total of 694[11] co-operative arrangements, with 59% of those arrangements entered into by 168 of the 270 small firms, followed by 28 of the 37 large firms with 23% of the arrangements.

By far the majority of arrangements could be found in the Human Health sector, with 114 out of 150 human health firms reporting 369 arrangements, more than 3 times as many arrangements as the next sector, agriculture with 110 arrangements by 50% of all agriculture biotech firms. The remaining 6 sectors have a range between 4% and 7% of total alliances. Provincially, Quebec firms have the most alliances with 70 of its 107 firms engaged in 271 arrangements, 39% of all arrangements. In British Columbia, 66% of biotechnology firms have entered into 162 different arrangements.

Firms entered into arrangements for a variety of purposes, but aiming to conduct research and development was the reason 33% of the time. Accessing knowledge (22%) and prototype development (18%) followed as reasons for entering an alliance. This trend was evident for both large and small firms, but for medium firms data was not available.

Overall firms joined with universities/hospitals in 30% of arrangements, followed by large firms with 28% of alliances. The majority of small firms indicated an equal number of arrangements with larger firms or universities/hospitals - 31% of the arrangements. Smaller or same sized firms made up 24% of alliances and government department/agencies 14%. The data tables contains additional data, and clearly further analysis is required to fully understand the nature of collaborative arrangements in Canada's biotechnology sector.

[10] See this article for case studies on the nature of strategic alliances in the biotechnology sector.
[11] Some respondents reported more than 1 agreement.

Table 9

Purpose of Collaborative Arrangements by Firm Size

1999									
Firm Size	Conduct R&D	Regulatory Affairs	Access Knowledge	Prototype Development	Access Markets	Access Capital	Intellectual Property Protection	Other	Total
Small	134	27	81	67	37	..	35	..	403
Medium	32	..	31	..	..	..	..	..	125*
Large	30	..	15	..	..	..	..	..	64
Total	195	33	128	104	48	..	51	..	591

Source: Statistics Canada

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Table 10
Number of Cooperative/Collaborative Agreements

1999

Firm Size	Number of Cooperative/Collaborative Agreements by Firm Size
Small	411
Medium	123
Large	160
Total	694

1999

Sector	Number of Cooperative/Collaborative Agreements by Sector
Human Health	369
Agriculture	110
Natural Resources	27
Environment	45
Aquaculture	33
Bioinformatics	35
Food	29
Other	46
Total	694

1999

Province	Number of Cooperative/Collaborative Agreements by Province
British Columbia	162
Alberta	53
Saskatchewan	23
Manitoba	..
Ontario	139
Quebec	271
Nova Scotia	..
Maritimes	..
Canada	694

Source: Statistics Canada

Preliminary Data

.. Figures not available

Table 11
Total Number of Cooperative/Collaborative Agreements by Type of Agreement & Firm Size

1999

	Firm Smaller or Equal Size	Larger Firm	Government Dept/Agency	University/ Hospital	Total
Small	98	128	57	128	411
Medium	..	..	27	38	141
Large	..	..	23	28	86
Total	**156**	**180**	**107**	**194**	**638**

Source: Statistics Canada

Preliminary Data

.. Figures not available

The reasons corporations spin-off companies are generally related to long-term benefits. Spinning off can create an entity to which the corporation can then endow research funds and write-off as expenses. As well, they typically form alliances that allow the parent company licensing of any current or future products, benefiting the spin-off as well as the parent company.

Intellectual property can be commercialized through the creation of a spin-off. The reasons for the spin-off can range from the need for streamlining operations to marketing control to the desire to allow the spin-off operation to operate freely. Reasons to spin-off can vary based on the between types of institutions holding the rights to potentially commercial developments. Government agencies and labs, universities and hospitals and private corporations all have different mandates and thus, a different reason to spin-off companies to capitalize on IP.

With corporate spin-offs, the result is often a technology transfer back to the original company. Universities, on the other hand, may have different reasons behind their decisions to spin-off IP. Universities may use this as a vehicle not just to commercialize a development, but also to give them greater access to R&D investments. It may also be a more effective way to maximize the return on their investment while, at the same time, increasing the university's academic and research profile. At Canadian universities spin-offs may also serve as an effective vehicle to keep talented researchers in close association with the universities. The reasons behind the creation of spin-offs at universities are similar to those of government agencies and laboratories. These institutions can make better use of different pools of R&D capital by creating private entities to commercialized developments. They can also streamline the commercialization of the development by removing it from bureaucratic entanglements.

The Statistics Canada *Survey of Intellectual Property Commercialization in the Higher Education Sector* (1999) found that the universities and hospitals have two choices of methods with which to commercialization – licensing and spin-offs, depending on whether the technology fits into an existing business and the availability of a licensee. Read states: "A spin-off may be formed if the technology requires further development or prototyping to demonstrate its commercial viability. Licensing can bring in a stable flow

of revenues in the short term. However, an institution that spins off a company may take an equity stake in the company in lieu of licensing fees, which can be more profitable over the long term"(p.22).

For purposes of the survey a spin-off firm is defined as a new firm created to transfer and commercialize inventions and technology developed in universities, firms or laboratories. Alternate definitions include the creation of a new firm by academia or government to develop a new technology or the creation of a new firm or by one or more businesses to develop and market a new product or technology.

Results from the survey indicate there were 123 spin-off firms among the 358 biotechnology firms in Canada in 1999. The majority (86%) of these firms is spun off from the university/hospital sector. And, perhaps as no surprise, is the fact most (91%) are found in the small firm category.

Table 12
Spin-off Firms by Size

	1999				
Firm Size	University/ Hospital	Another Company	Government Lab/Agency	Other	Total
Small	97	11	10	3	112
Medium	..	..	..	..	..
Large	..	..	..	..	..
Total	106	12	12	3	123

Source: Statistics Canada

Preliminary Data

.. Figures not available

The commercialization of intellectual property (IP) is a primary way in which these firms profit from their research. Another tool is licensing agreements. Licensing can bring immediate financial gain and require less of an investment in time and capital by the licensee. However, the benefits are generally more limited in terms of length of agreements and amounts returned to the licensee. Spin-offs, on the other hand, may offer a more profitable alternative but also a greater risk of failure and loss of commercialization potential for the entity that creates it. The result, therefore, involves a risk-reward decision to be made by the owner of the intellectual property.

Firms were asked to provide information on the exchange of intellectual property, from both the acquiring of IP and granting of IP perspective. Overall 79 firms (22% of the total 358 biotech firms) acquired 109 intellectual property rights from other firms. Rights were acquired from Canadian firms 45% of the time and from foreign firms for the balance. About 38% of the firms acquired rights from both Canadian and foreign firms. Although a similar number of firms granted rights the biotech sector was somewhat less active in actual number of rights granted. The 71 firms granted intellectual property rights to 37 Canadian firms and 50 to foreign firms.

Statistics Canada *Survey of Intellectual Property Commercialization in the Higher Education Sector* (1999) surveyed over 100 universities, degree-granting colleges and affiliated hospitals[12]. It found that over 60% of these institutions actively managed their intellectual property and within the past five years, 47% filed patent applications, 32% licensed their technologies. Although concepts differed it is useful to report that this group reported 471 spin-off companies of which 22% are in the biotechnology/biology field and 24% are found in the health sciences field.

Table 13
Transfer of Intellectual Property Rights

	1999
Total Acquired Rights to IP from Canadian Firms	49
Total Acquired Rights to IP from Foreign Firms	59
Total Acquired Rights	109
Total Number of Firms that Acquired Rights	**79**
Total Granted Rights to IP to Canadian Firms	37
Total Granted Rights to IP to Foreign Firms	50
Total Granted Rights	87
Total Number of Firms that Granted Rights	**71**

Source: Statistics Canada

Preliminary Data

.. Figures not available

In the competitive environment firms utilised numerous and multiple strategies. The 358 core firms identified the use of over 1000 strategies. Table 14 summarizes those strategies. Among the more popular strategies is growth, 55% of firms reported increased size as prime strategy, compared to only 11% that downsized. Over 1/3 of firms used product trials, refocused product development or new products as strategies to survive and thrive in the sector. Large firms used an average of 4.6 strategies per firm compared to small firms that used 2.6 strategies per firm. Perhaps this reflects larger firms having more options available to try. While small firms are more focused on developing new biotechnologies large firms are exploiting new biotechnologies or seeking to gain access to new biotechnologies using multiple strategies.

Table 14
Strategies Used in Firms in 1999 - By Firm Size

	1999															
Firm Size	Total Responses	Refocused Product Dev.	Downsized	Increased Size	Product Trials	New Product	Acquired Company	Out-Source Prod.	Licensed in Tech.	Licensed out Tech.	Merged	Joint Venture	Foreign Markets	No Change	Other
Small	696	85	29	161	75	76	17	46	47	24	13	26	56	..	..
Medium	189	23	..	21	40	26	..	15*	10	18*	..	..	..	..	..
Large	170	21	..	15	23	23	..	15	14	7	..	..	..	..	..
TOTAL	1054	129	39	198	137	125	32	77	71	49	25	47	62	35	7

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution: unreliable due to high coefficient of variation

[12] For complete discussion see: Read, C. (2000). *Survey of Intellectual Property Commercialization in the Higher Education Sector, 1999*. Working Paper Series, Statistics Canada, Ottawa.

Scientific Research and Experimental Development (SR&ED)

Governments offer a number of programs to assist firms, and perhaps one of the most visible is the Scientific Research and Experimental Development[13] (SR&ED) tax claim. SR&ED is defined in income tax legislation to systematic investigation or search carried out in a field of science or technology by means of experiment or analysis.

Under this program, the federal government provides income tax incentives to Canadian businesses that conduct scientific research and experimental development (SR&ED) in Canada. The program encourages industry, including small business and start-up firms, to develop technologically advanced products and processes. Claimants can apply for SR&ED investment tax credits for expenditures such as wages, materials, machinery, equipment, some overhead, and SR&ED contracts.

Generally, Canadian-controlled private corporations with less than $200,000 of taxable income can receive a refundable investment tax credit of up to 35% for qualifying SR&ED expenditures. An enriched refundable claim is subject to a limit of $2 million for qualifying expenditures. Most other Canadian corporations, proprietorships, partnerships, and trusts can receive an investment tax credit of up to 20% for qualifying SR&ED expenditures. In 1997, about $1.3 billion in assistance was provided to over 11,000 participants through the program. The number of claimants has grown at 13% a year since the beginning of the program in 1985.

To qualify for the SR&ED program, a project must advance the understanding of scientific relations or technologies; it must address scientific or technological uncertainty; and it must incorporate a systematic investigation by qualified personnel. Projects that qualify for SR&ED tax credits include:

- **experimental development** to achieve technological advancement to create new materials, devices, products, or processes, or improve existing ones;
- **applied research** to advance scientific knowledge with a specific practical application in view;
- **basic research** to advance scientific knowledge without a specific practical application in view; and
- **supporting work** in engineering, design, operations research, mathematical analysis, computer programming, data collection, testing, or psychological research --, i.e. if the work is commensurate with, and directly supports, the eligible basic or applied research, or experimental development.

Warda (1999) rated Canada as the only "leading promoter" of tax incentives for R&D tax treatment in a comparison with 10 other countries[14]. This system is based on a combination of federal and provincial tax incentives that evolved over a 30 year period and with eight of ten Canadian provinces offering tax incentives, "…[making the]

[13] This information is adapted from Canada Customs and Revenue Agency information. For example see circular CCRA 86-4R3 Scientific Research & Experimental Development

[14] This the highest of 4 categories. See his paper for complete discussion and analysis.

Canadian R&D tax treatment by far one of the most attractive tax incentive packages in the world". By comparison the United States, which uses a blend of federal and state income taxes much like the Canada system falls in the second category. Warda states: "The top ranking of Canada's R&D tax treatment internationally results from the combination of a "palatable pie" (the federal tax incentive program) and the "topping" (the tax treatment of R&D in the provinces that offer it), which makes the "pie" even more attractive. By and large, no country or state tax system of those examined in the study can measure up to the attractiveness of the R&D tax treatment in Canada and any of its provinces"(p14).

In 1999, 279 of the 358 core biotech firms applied for SR&ED. This would suggest based on the ability to carry forward the credit, firms were beginning to generate income for which accumulated SR&ED credits could be applied. Of the 79 that did not apply, 43% were uncertain of the eligibility requirements and less than 25% were dissuaded by the complexity of the application or did not meet eligibility requirements.

Table 15
Applications to the SRED Tax Credit Program in Past 5 Years

	1999
	Number of Firms
Applied for SRED	279
Total Did Not Apply For SRED	79
Complexity of the Application Process	18
Uncertainty of Eligibility	34*
Did Not Meet Eligibility Requirements	17
Other Reason	14

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999 Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

SRED: Sciecntific Research and Experimental Development

ELECTRONIC PUBLICATIONS AVAILABLE AT
www.statcan.ca

Patents

Patents are important to biotechnology firms in order to protect their intellectual properties. Patents serve to protect ideas or information that are easily transferred and used by any other capable firm. In short where knowledge is easily codifiable, it needs to be protected in order to capture the potential economic benefit. The patent also has the potential to create value in the firm. Biotechnology firms may not have large capital investments; the investment is in knowledge. That investment must be protected. Patents create a visible, tangible asset that can then be traded or used as guarantee for investors or to generate revenue. Biotechnology firms have been active in their patenting activity. Patents are useful indicators of developments in the biotechnology sector; in part because it is unlikely a firm would undertake a patent unless there was an intrinsic value to the object in question.

Canadian biotechnology firms held nearly 8000 pending and existing patents world-wide in 1999, split between 3706 existing patents and 4259 pending patents. Europe lead the number of patents with 2300, followed by the United States (U.S.) with 2166 and Canada with 1626. Nearly 75% of biotech firms are small, but they hold only 34% of patents. Large firms held over half of pending and existing patents. Nearly 1400 existing and pending patents were European patents held by large firms, almost double the number of patents held by large firms in Canada, and over 400 more than held in the U.S.A.. Generally large firms dominated patent ownership ranging from holding 45% of patents in the U.S. to 60% of patents in Europe. However among small firms patent holdings were grouped mainly in the U.S. with 31%, and Canada and Europe with 23% each.

The Canadian Intellectual Property Office (CIPO) maintains that patents serve two purposes. First they provide inventors monopolies on their creations creating incentive for research and development and second, patents serve as a means of technological exchange. The rights of Canadian patent are valid only in Canada, and foreign patents have no protective value in Canada. Patents must be sought for each country separately.

CIPO provides three basic criteria for patentability; an invention must be new (first in the world), second the invention must be useful and it must show inventive ingenuity. Of significance to the biotechnology sector is to note that patents are granted only for the physical embodiment of an idea, one cannot patent a scientific principle, an idea, or a medical treatment.

(Adapted from *A Guide to Patents* Canadian Intellectual Property Office, Industry Canada, Ottawa)

As a point of comparison results from the Statistics Canada *Survey of Intellectual Property Commercialization in the Higher Education Sector* (1999) found that the university community held a total of 1,826 patents in 1999 with 19% held in Canada, 52% in the United States and the rest in other countries.

These distributions can be in part explained by Rafiquzzaman & Whewell (1998) who examined patent activities and found that patenting by Canada abroad rose at a faster pace that foreign patenting in Canada. In 1978 the USA was the primary country for Canada to patent in, however, it declined in importance, losing share to France, Germany, Italy and Japan until 1992, the last year cited in the report. The authors assert that: "While the United States has become a less attractive country for Canadian patents over the years, it still receiver the largest share of attention from Canadian inventors. This is due to the larger market size of the United States and the high level of economic integration between the two countries." (p.11)

Canadian biotechnology firms submitted a total of 2266 application to domestic and foreign patent offices in 1998 (51%) and 1999 (49%). The majority, 36%, of these patents was submitted to the United States Patent & Trademark Office (USPTO), followed by 28% to the CIPO, 21% to the European Patent Office (EPO) and the balance of 16% to other offices. In 1998 the number of applications to CIPO and USPTO was almost equal, but in 1999 the number of Canadian patent applications dropped about 10%, while applications to U.S. authorities climbed by 26%. Submissions the EPO climbed by 13%. Applications to other offices fell 61% during the same period. Readers should note that it is possible for firms to have submitted patents on the same product to more than one office. Totals may not equal due to rounding. This is preliminary data.

Table 16

Pending and Existing Patents Held by Firms by Country of Patent

	1999					
	Canada	United States	Europe	Latin America	Asia	Total
Existing Patents	649	1,009	1,336	226	486	3,706
Pending Patents	977	1,157	964	331	830	4,259

Table 17

Patents (Pending & Existing) Held by Firms by Country of Patent and Firm Size

	1999					
Firm Size	Canada	United States	Europe	Latin America	Asia	Total
Small	614	849	618	190	432	2,702
Medium	262	348	295	49	205*	1,159
Large	750	969	1,386	318*	679	4,102
Total	**1,626**	**2,166**	**2,300**	**557**	**1,316**	**7,965**

Table 18

Pending and Existing Patents Held by Firms by Firm Size

	1999	
	Pending	Existing
Small	1 826	876
Medium	890	269
Large	1 542	2 560
Total	**4 259**	**3 705**

During the same time period, firms submitted 155 Plant Breeder Rights applications to domestic and foreign offices. Applications to the Canadian office accounted for 68% of all plant breeder applications. Few applications were made outside of Canada in 1998, less than 10% and in 1999 most applications (56%) were to the Canadian office followed by applications to the U.S. with 42%.

Table 19

Plant Breeders Rights Applications Submitted to Patent Offices 1998-1999

	Year	
	1998	**1999**
Can. Plants Breeders' Rights Office	52	54
Plant Variety Protection Office USDA	..	42
Community Plant Variety Office E.U.	..	..
Other	..	..
Total Plant Breeders Rights	**58**	**97**

Source: Statistics Canada

Preliminary Data

.. Figures not available

Raising Capital

Capital is essential to biotechnology. Firms face long and expensive research and development programs and often time lengthy approval processes, all prior to proving the commercial viability or marketing a product of a product. Firms search a variety of sources for capital, ranging from conventional sources such as banks to friends and relatives to testing the competitive venture capital waters. The need for new capital varies according the field of research, the stage of development and the past success in raising capital. The survival and success of a firm may depend on the ability to raise funds from a variety of sources. Access to capital was rated as a prime obstacle to the commercialization of biotechnology by the core biotechnology firms.

Niosi (2000b) summarizes some of the factors affecting a firm's ability to attract venture capital: "Patents usually helped to obtain venture capital, but some DBF's[15] with other assets had been successful in attracting this type of investment. Thus a few firms without patents, but having enrolled star scientists, or targeting very promising market niches, managed to get financed by venture capitalists" (p105). Eliasson believes that an entrepreneur requires competent venture capitalist, a source that is "capable of understanding innovators of radically new technology and be able to identify business needs and provides context" (p.34). Money is less important than the "competence to understand and identify winners and, hence, provide reasonably price equity funding" (ibid). These sources of capital are rare.

About 50% of biotechnology firms attempted to raise capital in 1999, with a success rate of 78%. Firms raised over $2 billion in capital, an average of $16 million per firm, however the 119 successful small firms raised on average $14 million. The human health sector lead with 81% of 104 firms attempting to raise capital, successfully raising $866 million in capital.

The most common capital source was venture capital funds with nearly a third of firm obtaining VC funding. The second most common source of capital was angel investors/family/friends, with over a 25% share. Conventional sources provided just 7% of capital raised to small firms, matching the contribution of assorted government sources. Large firms raised 22% of their capital from conventional sources. Initial public offering and collaborative alliances were unique techniques to the medium group for raising capital, and the angel investor category was used for less than 1/2 the distribution of capital as the small firm group.

[15] Dedicated Biotechnology Firm

Activity in the capital markets is expected to increase in 2002 when 206 firms plan to attempt to raise capital, compared to 178 in 1999. Almost half are human health firms, followed by the agriculture and environment sectors with about 15% each of the planned capital raising activity. Activity is expected to centre in Quebec where 85 of the 107 Quebec based firms are planning to raise capital. In Ontario, by comparison, only 36 of 111 firms expect to raise capital in 2002. Most firms (48%) plan to raise over $5 million in capital in 2002, while 37% plan to raise between $500 thousand and $5 million. The final 31 firms will raise less than $½ million.

Table 20a
Number of Firms that Attempted to Raise Capital for Biotechnology in 1999 by Size

	1999	
	Attempted to Raise Capital	Did not Attempt to Raise Capital
Small	149	121
Medium	24	27
Large	6	32
Total	178	180

Number of Firms that Attempted to Raise Capital for Biotechnology in 1999 by Province

	1999	
	Attempted to Raise Capital	Did not Attempt to Raise Capital
British Columbia	43	28
Alberta	14	14
Saskatchewan	..	12
Manitoba	..	..
Ontario	45	66
Quebec	62	44
Nova Scotia	..	..
Maritimes	..	12
Canada	178	180

Number of Firms that Attempted to Raise Capital for Biotechnology in 1999 by Sector

	1999	
	Attempted to Raise Capital	Did not Attempt to Raise Capital
Human Health	104	45
Agriculture	39	50
Natural Resources	4*	..
Environment	..	25*
Aquaculture	..	10
Bioinformatics	..	7
Food Processing	..	24
Other	4	7*
Total	178	180

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999 Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Table 20b

Number of Firms that were Successful Raising Capital by Size

	1999	
	Successfully Raised Capital in 1999	Unsuccessful in Raising Capital
Small	119	30
Medium	..	..
Large	..	..
Total	138	40

Number of Firms that were Successful Raising Capital by Province

	1999	
	Successfully Raised Capital in 1999	Unsuccessful in Raising Capital
British Columbia	33	10
Alberta	9	5
Saskatchewan	..	..
Manitoba	..	..
Ontario	39	6
Quebec	48	..
Nova Scotia	..	..
Maritimes	..	..
Canada	138	40

Number of Firms that were Successful Raising Capital by Sector

	1999	
	Successfully Raised Capital in 1999	Unsuccessful in Raising Capital
Human Health	84	19
Agriculture	30*	8
Natural Resources	4*	..
Environment	..	..
Aquaculture	..	..
Bioinformatics	8	..
Food Processing	..	..
Other	4	..
Total	138	40

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999 Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Table 20b

Amount of Capital Raised by Firm Size

	1999	
	Average Capital Raised per Firm ($000,000)	Total Capital Raised ($000,000)
Small	14*	1,690*
Medium	11	160
Large	66	297
Total	**16**	**2,147**

Amount of Capital Raised by Province

	1999	
	Average Capital Raised per Firm ($000,000)	Total Capital Raised ($000,000)
British Columbia	16	545
Alberta	5	50
Saskatchewan	..	..
Manitoba	..	..
Ontario	5	175
Quebec	27*	1,301*
Nova Scotia	11	..
Maritimes	14	63
Canada	**16**	**2,147**

Table 20b

Sources of Capital by Firm Size (% distribution)

	1999						
	Angel Investors/Family/ Friend	Government Loans/Grants/ Incentives	Venture Capital Funds	Conventional Sources	Initial Public Offering	Collaborative Alliance	Other
Small	30	7	32	7	1	3	18
Medium	12	8*	22	2	13	15	19
Large	..	..	22	22	..	..	56
Total	27	7	30	7	2	4	19

Sources of Capital by Province (% distribution)

	1999						
	Angel Investors/Family/ Friend	Government Loans/Grants/ Incentives	Venture Capital Funds	Conventional Sources	Initial Public Offering	Collaborative Alliance	Other
British Columbia	26	..	48	7*	..	..	13
Alberta	51	..	..	..	1	..	28
Saskatchewan	..	..	..	..	..	..	..
Manitoba	..	..	..	..	..	..	..
Ontario	19*	..	15*	14	..	11*	32*
Quebec	35	11	34	4	2	3	12
Nova Scotia	..	3	69	7	..	..	21
Maritimes	..	2	76	6	..	..	17
Canada	27	7	30	7	2	4	19

Percentages (%) may not equal 100 due to rounding

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Table 20c

Number of Firms Planning to Raise Capital in 2002 by Size

	1999	
	Plans to Raise Capital in 2002	Does Not Plan to Raise Capital in 2002
Small	160	109
Medium	38	13
Large	8	29
Total	206	152

Number of Firms Planning to Raise Capital in 2002 by Sector

	1999	
	Plans to Raise Capital in 2002	Does Not Plan to Raise Capital in 2002
Human Health	101	48
Agriculture	32	57
Natural Resources	3*	12
Environment	30	6*
Aquaculture	9	6
Bioinformatics	16	..
Food Processing	9*	19
Other	6	..
Total	206	152

Number of Firms Planning to Raise Capital in 2002 by Province

	1999	
	Plans to Raise Capital in 2002	Does Not Plan to Raise Capital in 2002
British Columbia	45	26
Alberta	16	12
Saskatchewan	6	10
Manitoba	3	..
Ontario	36	75
Quebec	85	21
Nova Scotia	6	..
Maritimes	14	..
Canada	206	152

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Table 20c

Forecast for Raising Capital in 2002 by Size

	1999		
	Less Than $500,000	From $500,000 to $5,000,000	More Than $5,000,000
Small	16	64	80
Medium	..	..	14
Large	..	..	5
Total	31	76	99

Forecast for Raising Capital in 2002 by Province

	1999		
	Less Than $500,000	From $500,000 to $5,000,000	More Than $5,000,000
British Columbia	7	15	23
Alberta	..	5	8
Saskatchewan	..	6	..
Manitoba	..	..	..
Ontario	7	11	18
Quebec	..	26	44
Nova Scotia	..	5*	..
Maritimes	..	11*	..
Canada	31	76	99

Forecast for Raising Capital in 2002 by Sector

	1999		
	Less Than $500,000	From $500,000 to $5,000,000	More Than $5,000,000
Human Health	7	24	70
Agriculture	7*	15	10
Natural Resources	..	3*	..
Environment	..	19*	..
Aquaculture	..	6*	..
Bioinformatics	3*	..	11
Food Processing	..	..	..
Other	..	..	..
Total	31	76	99

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Biotechnology Firm Import & Export Activities

The Canadian Biotechnology Advisory Committee[16] recently reported that the world market for biotechnology-based products will increase from $20 billion in 1995 to $50 billion in 2005. This growth, both real and anticipated of biotechnology products suggests an increasingly significant opportunity in international trade. Biotechnologies are new products and processes and are the result of intensive research and development programs or the integration of other innovative processes or products in creating value-added products that could hold great significance for Canada's export market. Canada has a relatively small domestic market and increased foreign trade may be essential for firms to reach markets large enough to recoup the costs of development, making projects feasible.

Biotechnology exports[17] play an increasingly important role in the revenues of biotechnology firms. Biotechnology exports are expected by respondents to dramatically increase from $372 million in 1998, approaching $1.7 billion in 2002, while becoming a growing proportion of total exports for biotechnology firms. Export revenues for the 208-exporting firms were over $2.5 billion, of which biotechnology contributed less than 30% of the total. Biotechnology accounted for 52% of exports for small firms. In contrast biotechnology exports accounted for 26% of total exports in large firms.

Biotechnology exports are expected to grow over 400% between 1999 and 2002 in the small firm sector and are expected to account for almost 75% of small firm total exports. In the medium sized firm group, growth is expected to almost triple the value of biotechnology exports from $51 million to $152 million. The proportion of exports from biotechnology is expected to grow from less than 30% in 1998 to over 50% in 2002. Export growth in the large firms is expected to be 23%, but the proportion of exports from biotechnology is expected to increase from 26% of total exports in 1999 to over 40% in 2002.

Firms were asked to provide the destination of exports and to provide an estimate for 2002. The major trade partner comes as no surprise, overall 51% of biotechnology exports are sent to the United States, followed by Europe with 23% and Asia with 10%. These patterns are expected to only subtly change in 2002. Large firms had the highest percentage of exports to the U.S., at 64%, compared to small firms with 48%. However small firms sent 24% of their exports to Europe compared to large firms that sent only 15% of exports to Europe in 1999.

On a provincial basis British Columbia leads in export activity with Asia. Quebec exports 42% of its biotechnology to Europe, eclipsing its trade with the U.S. As a region the Maritimes also has Europe as its major export destination, even though as Nova Scotia sends 87% of its exports to the U.S., the highest percentage of any province. Natural resource firms sent 90% of their exports to the United States, with the balance going to

---

[16] Canadian Biotechnology Advisory Committee Annual Report 1999-2000

[17] For additional information on exports and imports see the working paper *Biotechnology Use & Development –1999.*

Asia. The bioinformatics sector saw Europe as the prime export destination, followed closely by the U.S.

On the import side the USA was the primary source for biotechnology imports, at 54%, but this ranged from 66% for small firms down to 32% for large firms who's major import source was Europe. In 2002 firms expect that imports from the USA will drop to 43%, and increase from Europe by 3% to 28%.

Table 21 (1999)

Geographic Distribution (%) of Exports by Size

	USA	Europe	Latin America	Asia
Small	48	24	2	10
Medium	59	28	1	3
Large	64	15	6*	11
Total	51	23	2	9

Geographic Distribution (%) of Exports by Province

	USA	Europe	Latin America	Asia
British Columbia	51	9	..	14
Alberta	72	4	..	10
Saskatchewan	84	11	1	4
Manitoba	67	19	0	2
Ontario	47	24	4*	11
Quebec	40	42	2	5
Nova Scotia	87	8*	..	2*
Maritimes	33	51	1	4
Canada	51	23	2	9

Geographic Distribution (%) of Exports by Sector

	USA	Europe	Latin America	Asia
Human Health	56	25	3	7
Agriculture	58	8	1	14
Natural Resources	90	..	..	9
Environment	46	34	1	13
Aquaculture	..	..	..	..
Bioinformatics	45	48	1	3
Food Processing	65	21	..	11
Other	..	..	..	..
Total	**51**	**23**	**2**	**9**

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Note: Due to rounding, components may not add to totals

Table 22 (2002)

Geographic Distribution (%) of Exports by Size

	USA	Europe	Latin America	Asia
Small	50	21	4	9
Medium	52	21	1	6
Large	66	15	4	6
Total	**52**	**20**	**4**	**8**

Geographic Distribution (%) of Exports by Province

	USA	Europe	Latin America	Asia
British Columbia	47	18	8	10
Alberta	64	13	3*	10
Saskatchewan	62	22	3	6
Manitoba	59	10	1	3
Ontario	51	26	2	8
Quebec	47	18	2	8
Nova Scotia	62	23	5	..
Maritimes	64	26	3	6*
Canada	**52**	**20**	**4**	**8**

Geographic Distribution (%) of Exports by Sector

	USA	Europe	Latin America	Asia
Human Health	54	23	3	6
Agriculture	52	16	3	12
Natural Resources	50	10	..	6*
Environment	..	..	..	..
Aquaculture	..	..	..	..
Bioinformatics	59	23	1	3
Food Processing	61	10	..	9
Other	..	..	..	..
Total	**52**	**20**	**4**	**8**

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Note: Due to rounding, components may not add to totals

Table 23 (1999)
Geographic Distribution (%) of Imports by Size

	USA	Europe	Latin America	Asia
Small	66	16	..	..
Medium	35	35	..	..
Large	32	46	..	..
Total	**54**	**25**	..	..

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Note: Due to rounding, components may not add to totals

Table 24 (2002)
Geographic Distribution (%) of Imports by Size

	USA	Europe	Latin America	Asia
Small	43	27	..	..
Medium	40	35	..	..
Large	46	18	..	..
Total	**43**	**28**	..	..

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Note: Due to rounding, components may not add to totals

Human Resources

Biotechnology is an enabling technology implicit to a wide variety of applications. The biotechnology sector is dynamic, growing and global. Human resources are essential to the biotechnology sector where value is not measured in bricks and mortar or units produced but in knowledge. The knowledge to create and build new products and processes. As developed economies place increasing emphasis on skilled knowledge workers, the success of any industry is becoming more highly dependent upon the ability to attract, supply and retain individual workers with the right skills at the right time. The biotechnology sector is an example of a sector where access to a highly skilled knowledge workforce is a critical factor in the success of the overall industry. As such, understanding the biotechnology labour market and its trends are essential components of a human resources strategy. Industry Canada[18] suggests that biotechnology is moving into its next phase, a 10-year period of rapid expansion in global demand. A key element is human resources.

[18] *Pathways to Growth: Opportunities in Biotechnology*, (2000) Industry Canada. Ottawa

For sectors, such as biotechnology to succeed in the knowledge-based economy, skills are vitally important. As Canada continues the transition to the knowledge-based economy, the stock of skills and capacity to develop skills will impact knowledge based sectors like biotechnology and its economic prospects. But skills alone will not guarantee success. In addition to a strong skill development and learning systems the existence of exchange networks to carry goods and services and increasingly, information and ideas across the country and around the world is required. Also required are the systems and processes to create knowledge and to utilize new knowledge through innovation and technology transfer, and translate new knowledge into commercial products. These activities and others require highly skilled human resources, not just in the scientific sector but in business and regulatory activities.

In 1999, Biotechnology firms have employed[19] a total 7748[20] people, mainly in the human health sector. This represents about 12% of the total workforce of 62,613 employees working in core biotechnology firms. Biotechnology employees are centred in human health with just over 70% of all biotechnology employees, followed by agriculture with 13% and food processing with 4% each.

Over 40% of total employees in the human health sector are biotechnology employees compared to next highest sector, agriculture, where nearly 1000 biotechnology employees make up 5% of the total workforce of biotechnology companies. Four out of eight sectors exceed 10,000 total employees but biotechnology makes up only a small proportion of their total workforce. Ontario and Quebec are almost tied in the number of biotechnology employees with over 2,500 each and each province comprises about one third of the biotechnology workforce. However in Quebec over 90% of the employees are full-time compared to 70% employed full time in Ontario. British Columbia has about 15% of the biotechnology work force.

Biotechnology employees are mainly found in the large firm category with 45% of employees and small firms with 38% of the biotechnology employees. However, the ratio of biotechnology employees to total employees is very different. In the small firm category 60% of the employees have biotechnology responsibilities, while in the large category biotechnology employees make up 7% of the workforce.

In addition to regular employees, 223 firms in all sectors hired students, although less than 60% of small firms hired students. The majority of students were hired at the undergraduate level, but graduate level students, a much smaller pool were hired by 37% of biotechnology firms. Students are important for the future since they will be developing an in-depth knowledge of biotechnology and may have the opportunity to make a contribution.

---

[19] In 1999, a report published by BIOTECanada and based on data from Statistics Canada Biotechnology Firms Survey - 1997 showed total biotechnology employment as 9,823. Since the two surveys are different, including different methodologies, questions and estimation procedures, it is premature to conclude a decrease in biotechnology employment. A comparison between the two surveys requires detailed further study and will be the subject of a future paper. This section looks only at the 1999 results.

[20] These are revised figures

Table 25

Total Number of Employees and Biotech Employees by Size

1999

	Total Number of Employees	Total Number of Biotech Employees
Small	4,907	2,935
Medium	4,673	1,343
Large	53,033	3,470
Canada	62,613	7,748

Total Number of Employees and Biotech Employees by Province

1999

	Total Number of Employees	Total Number of Biotech Employees
British Columbia	7,558	1,191
Alberta	..	577
Saskatchewan	4,769	291
Manitoba	635	357
Ontario	14,568	2,561
Quebec	31,060	2,588
Nova Scotia	108	77
Maritimes	679	183
Canada	62,613	7,748

Total Number of Employees and Biotech Employees by Sector

1999

	Total Number of Employees	Total Number of Biotech Employees
Human Health	12,975	5,487
Agriculture	18,066	985
Natural Resources	12,710	149
Environment	4,187	323
Aquaculture	232	166
Bio Informatics	368	227
Food Processing	13,866	338
Other	..	..
Canada	62,613	7,748

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Note: This is revised data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Table 26

Number of Firms with Full and Part Time Biotech Employees by Size

	1999											
	Scientific/ Research Direction Full Time	Scientific/ Research Direction Part Time	Technicians/ Engineering Full Time	Technicians/ Engineering Part Time	Regulatory/ Clinical Affairs Full Time	Regulatory/ Clinical Affairs Part Time	Production Full Time	Production Part Time	Finance/ Administration Full Time	Finance/ Administration Part Time	Management/ Licensing/ Administration Full Time	Management/ Licensing/ Administration Part Time
Small	194	75	134	81	56	14	87	37	98	24	112	25
Medium	47	8	36	22*	19	18*	34	..	28	..	30	..
Large	33	16	21	12	19	7	19	..	13	..	14	..
Canada	**273**	**99**	**191**	**115**	**94**	**38**	**140**	**42**	**139**	**41**	**156**	**43**

Number of Firms with Full and Part Time Biotech Employees by Sector

	1999											
	Scientific/ Research Direction Full Time	Scientific/ Research Direction Part Time	Technicians/ Engineering Full Time	Technicians/ Engineering Part Time	Regulatory/ Clinical Affairs Full Time	Regulatory/ Clinical Affairs Part Time	Production Full Time	Production Part Time	Finance/ Administration Full Time	Finance/ Administration Part Time	Management/ Licensing/ Administration Full Time	Management/ Licensing/ Administration Part Time
Human Health	132	28	98	31	63	19	61	13	75	19	90	18
Agriculture	58	31*	34	34*	13	5*	23	..	22	5	28	6
Natural Resources	12	7	10	8	..	..	..	..	6*	..	..	..
Environment	24*	10*	16*	21*	..	11*	22*	..	14*	11*	16*	11*
Aquaculture	9	3*	11	..	..	..	..	..	7*	..	..	..
Bio Informatics	18	6	14	4*	..	..	5	..	9	..	..	3*
Food Processing	16	11*	7	16	..	..	18	..	6	..	9	..
Other	..	..	..	..	..	..	..	..	..	..	..	..
Canada	273	99	191	115	94	38	140	42	139	41	156	43

Number of Firms with Full and Part Time Biotech Employees by Province

	1999											
	Scientific/ Research Direction Full Time	Scientific/ Research Direction Part Time	Technicians/ Engineering Full Time	Technicians/ Engineering Part Time	Regulatory/ Clinical Affairs Full Time	Regulatory/ Clinical Affairs Part Time	Production Full Time	Production Part Time	Finance/ Administration Full Time	Finance/ Administration Part Time	Management/ Licensing/ Administration Full Time	Management/ Licensing/ Administration Part Time
British Columbia	56	17	44	19	11	4	26	12	34	7	37	8
Alberta	26	6	16	8	7	..	13	..	15	..	16	..
Saskatchewan	13	..	..	6*	..	..	7	..	7	..	7	..
Manitoba	5	..	..	..	..	..	2	..	..	..	..	..
Ontario	65	38	41	47	28	..	38	..	25	..	42	10
Quebec	96	21	69	28	26	17*	50	13	49	18*	47	18*
Nova Scotia	7	..	3	..	4	..	4	..	3	..	..	..
Maritimes	13	..	8	..	5	..	5	..	8	..	..	..
Canada	**273**	**99**	**191**	**115**	**94**	**38**	**140**	**42**	**139**	**41**	**156**	**43**

Table 27

Number of Full and Part Time Biotech Employees by Size

1999

	Scientific/ Research Direction Full Time	Scientific/ Research Direction Part Time	Technician/ Engineer Full Time	Technician/ Engineer Part Time	Regulatory/ Clinical Aff. Full Time	Regulatory/ Clinical Aff. Part Time	Production Full Time	Production Part Time	Finance/ Admin. Full Time	Finance/ Admin. Part Time	Managt/ Licensing/ Admin. Full Time	Managt/ Licensing/ Admin. Part Time	Total Full Time	Total Part Time
Small	870	112	783	149	86	20	277	83	215	39	235	67	2,467	469
Medium	216	9	248	79	100	47	191	..	259	..	145	..	1,159	184
Large	806	88	589	75	297	38*	956	..	66	..	127	..	2,840	630*
Canada	1,891	209	1,621	303	484	105	1,424	306	540	167	506	193	6,466	1,282

Number of Full and Part Time Biotech Employees by Sector

1999

	Scientific/ Research Direction Full Time	Scientific/ Research Direction Part Time	Technician/ Engineer Full Time	Technician/ Engineer Part Time	Regulatory/ Clinical Aff. Full Time	Regulatory/ Clinical Aff. Part Time	Production Full Time	Production Part Time	Finance/ Admin. Full Time	Finance/ Admin. Part Time	Managt/ Licensing/ Admin. Full Time	Managt/ Licensing/ Admin. Part Time	Total Full Time	Total Part Time
Human Health	1,382	104	1,016	130	440	88	1,027	254*	374	125*	382	157*	4,620	857
Agriculture	281	46	235	60	27	7	116	..	89	23	53	19	800	179
Natural Resources	35	10*	31	27	..	..	..	..	4	..	..	..	78	39
Environment	42	19	46	49*	..	7	..	..	16	..	..	7	221*	102
Aquaculture	54	7	93	..	..	..	..	..	11	..	..	..	149	17*
Bio Informatics	605	8*	93	11*	..	..	5	..	16	..	12	7*	183	29
Food Processing	52*	11*	..	21*	..	..	139	..	11	..	11*	..	296	42
Other	21	..	..	..	..	..	..	..	20	..	9	..	119	18
Canada	1,891	209	1,621	303	484	105	1,424	306	540	167	506	193	6,466	1,282

Number of Full and Part Time Biotech Employees by Province

1999

	Scientific/ Research Direction Full Time	Scientific/ Research Direction Part Time	Technician/ Engineer Full Time	Technician/ Engineer Part Time	Regulatory/ Clinical Aff. Full Time	Regulatory/ Clinical Aff. Part Time	Production Full Time	Production Part Time	Finance/ Admin. Full Time	Finance/ Admin. Part Time	Managt/ Licensing/ Admin. Full Time	Managt/ Licensing/ Admin. Part Time	Total Full Time	Total Part Time
British Columbia	344	27	290	64	71	32*	94	29	56	15	129	41	984	207
Alberta	129	9	87	15*	36	..	146*	..	76*	..	56	..	529	48*
Saskatchewan	69	..	..	8	..	..	38	..	30	..	17	..	274*	17
Manitoba	27	..	..	..	..	..	125*	7	9	..	18*	..	325*	33
Ontario	459	106	285	121	149	54	671*	..	159*	..	103	125*	1,827	735*
Quebec	825	33	684	85	159	12	336	30	198	34*	172	22	2,372	216
Nova Scotia	22	..	19	..	6	..	12	..	4	..	9	..	73	..
Maritimes	39	19	71	..	7	..	15	..	13	..	10	..	156	..
Canada	1,891	209	1,621	303	484	105	1,424	306	540	167	506	193	6,466	1,282

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Table 28

Number of Firms Employing Students by Level of Education and by Size

	1999		
	Technical/Trade/ College	Undergraduate Level	Graduate Level
Small	65	104	98
Medium	26*	36	13
Large	11	29	20
Canada	102	169	131

Number of Firms Employing Students by Level of Education and by Province

	1999		
	Technical/Trade/ College	Undergraduate Level	Graduate Level
British Columbia	16	34	24
Alberta	4	14	9
Saskatchewan	6	5	8
Manitoba	..	3	3
Ontario	32	45	38
Quebec	36	60	42
Nova Scotia	..	5*	..
Maritimes	..	7	..
Canada	102	169	131

Number of Firms Employing Students by Level of Education and by Sector

	1999		
	Technical/Trade/ College	Undergraduate Level	Graduate Level
Human Health	45	86	65
Agriculture	15	26	25
Natural Resources	..	6	..
Environment	..	22*	..
Aquaculture	..	5*	5*
Bio Informatics	9	7	10
Food Processing	3*	8	8*
Other	7*	5	5
Canada	102	169	131

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Table 29

Number of Firms Employing Students by Size

1999

	Firms Hiring Students	Firms not Hiring Students
Small	153	116
Medium	39	12
Large	31	7
Canada	223	135

Number of Firms Employing Students by Province

1999

	Firms Hiring Students	Firms not Hiring Students
British Columbia	40	31
Alberta	16	12
Saskatchewan	9	7
Manitoba	5	..
Ontario	62	50*
Quebec	79	27
Nova Scotia	5*	..
Maritimes	12*	..
Canada	223	135

Number of Firms Employing Students by Sector

1999

	Firms Hiring Students	Firms not Hiring Students
Human Health	104	45
Agriculture	43	46*
Natural Resources	6	9
Environment	27*	8
Aquaculture	5*	9
Bio Informatics	14	..
Food Processing	14	14
Other	9	..
Canada	223	135

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999 Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Of particular interest is the number of highly skilled knowledge workers. Nearly 30% of full-time employees are classed as full-time scientific/research direction, with the technician/engineering group comprising another 25%. The majority of these two groups are found working in the human health sector. Over 70% of the full-time production employees are found in the human health sector, mainly in large firms.

Much discussion has focused on the lack of highly skilled knowledge workers for the biotechnology sector. In all 92 firms reported as total of 537 unfilled positions, mainly (49% of unfilled positions) in the human health sector. In all the human health sector had 86% of all the unfilled positions, which represents about 10% of the human health sector employees. The 537 unfilled positions represents 8% of all full-time positions and 7% of all biotech employees. The scientific category had a total of 172 vacancies, followed by the technician category. The main reason firms provided for unfilled positions were a lack of qualified candidates.

Table 30

Number of Firms with Unfilled Positions by Size

	1999	
	Unfilled Positions	No Unfilled Positions
Small	67	202
Medium	14	37
Large	11	26
Canada	92	266

Number of Firms with Unfilled Positions by Province

	1999	
	Unfilled Positions	No Unfilled Positions
British Columbia	23	48
Alberta	10	18
Saskatchewan	..	14
Manitoba	..	..
Ontario	28	84
Quebec	22	85
Nova Scotia	5	..
Maritimes	5	14
Canada	92	266

Number of Firms with Unfilled Positions by Sector

	1999	
	Unfilled Positions	No Unfilled Positions
Human Health	71	78
Agriculture	9	79
Natural Resources	..	14
Environment	..	35
Aquaculture	..	14
Bio Informatics	8	9
Food Processing	..	27
Other	..	9
Canada	92	266

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999 Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Table 31
Number of Unfilled Positions by Size

	1999						
	Scientific/ Research Direction	Technicians/ Engineering	Regulatory/ Clinical Affairs	Production	Finance/ Administration	Management/ Licensing/ Administration	Total
Small	116	97	18	20	21	31	303
Medium	18	22	13	16	..	..	90
Large	38	24	25	27	..	..	144
Canada	172	143	56	63	31	72	537

Number of Unfilled Positions by Province

	1999						
	Scientific/ Research Direction	Technicians/ Engineering	Regulatory/ Clinical Affairs	Production	Finance/ Administration	Management/ Licensing/ Administration	Total
British Columbia	67	53	16	9	7	38	190
Alberta	..	..	..	..	6*	..	29
Saskatchewan	..	..	..	..	..	..	..
Manitoba	..	..	5	..	..	..	25
Ontario	44	39	19	29	6*	18	155
Quebec	38	43	14	9	10	11	124
Nova Scotia	..	4*	..	..	..	..	9*
Maritimes	..	4*	..	..	..	..	9*
Canada	172	143	56	63	31	72	537

Number of Unfilled Positions by Sector

	1999						
	Scientific/ Research Direction	Technicians/ Engineering	Regulatory/ Clinical Affairs	Production	Finance/ Administration	Management/ Licensing/ Administration	Total
Human Health	148	115	56	61	23	60	462
Agriculture	14*	13*	..	..	..	11	42
Natural Resources	..	..	..	..	..	..	..
Environment	..	..	..	..	..	..	..
Aquaculture	..	..	..	..	..	..	..
Bio Informatics	9*	14	..	..	..	..	28
Food Processing	..	..	..	..	..	..	..
Other	..	..	..	..	..	..	..
Canada	172	143	56	63	31	72	537

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Table 32
Reasons for Unfilled Positions by Employment Category

	1999		
Position Type	Lack of Qualified Candidates	Compensation too High	Other
Scientific/Research Direction	45	23	19
Technicians/Engineering	18	6	30
Regulatory/Clinical Affairs	15	10	7
Production	13	6	11
Finance/Marketing	4	8	10
Management	9	8	11

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999

Preliminary Data

.. Figures not available

* Use with caution, unreliable due to high coefficient of variation

Firms utilized a wide variety of topics in order to attract new staff, with the most common methods cited by firms being university recruitment, networking and newspaper/journal ads. The least common methods were to use over qualified or under qualified staff, mainly a technique used by small firms. Another method of finding staff was to seek personnel from outside of Canada. This was attempted by 25% of biotech firms roughly in the same proportion as their size distribution. Of these 88 firms, 56 successfully hired 205 staff. These firms hired on average 4 people. Most people were hired from the United States, followed closely by European countries.

Table 33

Strategies Used when Recruiting by Size

	1999										
	Internet Resources	University Recruitment	Use Under-Qualified Staff	Temporary/ Contract Staff	Employment Agencies	In-House Training	Use Over-Qualified Staff	Networking	Newspaper/ Journal Ads	Professional Associations	Other
Small	120	151	19	68	62	104	15	160	132	63	19
Medium	20	31		11	21*	23		26	41		
Large	16	27		17	15	21		23	28		
Total	156	209	22	95	98	148	20	208	201	92	25

Strategies Used when Recruiting by Province

	1999										
	Internet Resources	University Recruitment	Use Under-Qualified Staff	Temporary/ Contract Staff	Employment Agencies	In-House Training	Use Over-Qualified Staff	Networking	Newspaper/ Journal Ads	Professional Associations	Other
British Columbia	31	41	4	28	16	44	4	38	40	20	
Alberta	14	17		7	3			13	17	5	
Saskatchewan		5	3	6	3*	9		10	9	9	
Manitoba	6	3				4		6	6		
Ontario	41	47	7	29	33	35	5	74	54	21	7
Québec	51	78		16	36	41	5	61	67	29	13
Nova Scotia		7						4			
Maritimes	11*	18				14*		8			
Canada	156	209	22	95	98	148	20	208	201	92	25

Strategies Used when Recruiting by Sector

	1999										
	Internet Resources	University Recruitment	Use Under-Qualified Staff	Temporary/ Contract Staff	Employment Agencies	In-House Training	Use Over-Qualified Staff	Networking	Newspaper/ Journal Ads	Professional Associations	Other
Human Health	92	95	12	54	56	64	12	99	92	45	13
Agriculture	25	40	4	17	14	24		56	43	14	4
Natural Resources	4*	10				7		9	9		
Environment	10*	20*							24*	20*	
Aquaculture	4	9		7*		10		9	6	3	
Bioinformatics	13	12			6	8		7	9		
Food Processing		15		6*	3*	12		13*	13	6*	
Other		7						4	4		
Total	156	209	22	95	98	148	20	208	201	92	25

Table 34
Number of Firms Attempting to Hire
Biotechnology Personnel Outside of Canada

	1999	
	Attempted	Did Not Attempt
Small	64	205
Medium	11	40
Large	12	25
Total	88	269

Table 35
Geographic Source of Personnel Hired

	1999				
	USA	Europe	Asia	Latin America	Other
Small	43	33	19	..	..
Medium	4	8	..	..	..
Large	10	9	..	..	..
Total	57	50	19	3	7

Table 36
Number of Firms Successful & Unsuccessful in
Hiring Personnel Outside Canada

	1999	
	Successful	Unsuccessful
Small	36	29
Medium	8	3
Large	12	0
Total	56	32

Table 37
Number of Employees Hired From Outside of Canada

	1999	
	Mean Per Firm	Total
Small	3	105
Medium	2	15
Large	7	85
Total	4	205

Source: Statistics Canada, Biotechnology Use and Development Survey - 1999
Preliminary Data
.. Figures not available
* Use with caution, unreliable due to high coefficient of variation

Methodology

The survey was mailed to 3377 firms in selected NAICS codes in May 2000. The sample drawn from the Business Register of Statistics Canada was supplemented by a list of firms prepared by industry experts. Biotechnology does not fit into a single NAICS code so the need to sample based on the possibility of biotechnology use is required. Selected NAICS codes, mainly in the manufacturing sector, were identified as sectors of the economy where there was the possibility of firms using biotechnologies. Firms were selected to provide a representative sample based on size, industry, and province. Overall response rate was 66%. Results from this survey were weighted to reflect the entire count of firms in the selected industry sectors.

Excluded from the sample and from the estimates are the very small biotechnology firms. These firms had less than 5 employees and less than $100,000 in research and development expenditures. The impact on the results was minimal, for example less than 1% of biotechnology research and development expenditures and new product and processes.

The questionnaire was compiled and written with the active input of a consultation group of biotechnology experts from a variety of areas of expertise and interest. Following its initial design, the questionnaire was field tested with potential respondents, whose comments on the design and content were then incorporated into the questionnaire.

A challenge facing the survey, and indeed all research into the nature of the biotechnology sector, is the fact that biotechnology is not a single product or process nor a single group of products or processes. It is a broad spectrum of products and processes spanning human health, agriculture, environmental and other industries and classifications. The sampling techniques reflect this so that the sample reflects not a single well-defined industry but a developing sector with a multitude of characteristics, some known and some less known.

Definitions

Debate on what constitutes biotechnology continues and one of the threads of debate is the debate between old biotechnologies and new biotechnologies. Old biotechnologies include traditional fermentation and yoghurt making. The new biotechnologies build on the advances in science in the 1970's and 80's. This survey does not attempt to reconcile that debate, but did actively seek out the use of the new biotechnologies, developed in the past several decades, as opposed to the more traditional biotechnologies such as fermentation.

As part of its ongoing initiatives, the Division is actively involved with the OECD where consensus has been reached on a provisional list based definition for biotechnology. The definition, adopted after the administration of this survey, is a revision the list of biotechnologies developed by Statistics Canada and other countries and used in Question

1. It will be incorporated into the next survey. Several methods of defining biotechnology were attempted prior to the survey and a list-based definition emerged as the preferred method for test respondents. The list of biotechnologies used is question 1, page 2 of the questionnaire, found in Appendix 1.

Classifications

This report uses a series of classifications in data tables. These are firm size, sector and geography.

Geography is the standard geography classifications of Statistics Canada[21]

Size is based on the number of employees a firm reports:

Small - 50 or fewer employees
Medium - 51 to 150 employees
Large - 151 or more employees

Sector consists of 8 groups including an 'other' category. These categories are human health, agriculture, natural resources, environment, aquaculture, bioinformatics, and food processing. Additional detail for each of these categories can be found on page 7, Question 9 of the questionnaire contained in Appendix 1.

Data Quality

This survey, as with all surveys using a sample, must reach a balance between time, cost and the quality of data. In cases where the quality of data is questionable based on a high coefficient of variation or for other reasons the data is either not published or indicated as being unreliable. Data users are reminded to use this data with caution. Data that could in any way be used to identify a firm was suppressed to ensure confidentiality.

Some figures used in this publication are revised figures of the originally published preliminary results. Other data is preliminary data and may be revised. Data are estimates based on weighted responses, and were subjected to an intensive follow-up, editing and imputation process. Users are also cautioned in making direct comparisons to the 1997 data. Some of the concepts and methods are different. Efforts to harmonize the two surveys are nearly complete.

Respondent Categories

The questionnaire was designed to alleviate respondent burden as much as possible. For example the first group of respondents, the non-users of biotechnology, was able to quickly exit the survey with minimal effort. The second group, biotechnology users answered a series of questions covering 3 additional pages, while core respondents completed the full survey. Respondent testing of the survey revealed that the full

[21] For a full discussion see Census Dictionary, Geography Division, Statistics Canada

questionnaire could be completed in 1.5 hours. The frequency of the survey is planned for every second year.

The survey was designed to capture data from three distinct groups. The first group do not use biotechnology. This non-users group provided information on why they did not use biotechnologies, by responding to questions 1 and 2 in the survey. The second group is the firms that use biotechnologies as part of their day-to-day operations, as they would use any other factor of production. For this group biotechnologies are simply an expedient way of conducting business. This group responded to questions 1, 3, 4, 5, 6, 7, and 8 of the questionnaire. Characteristics of these two groups will be reported on in a forthcoming paper.

The final group is the core firms. These firms are conducting an active research and development program in biotechnology and consider biotechnology central to their activities. This group completed the entire survey with the exception of question 2. This group of 358 firms is the focus of this paper and a prior paper.

ELECTRONIC PUBLICATIONS AVAILABLE AT
www.statcan.ca

Bibliography

Arundel, A. & A. Rose (1999a) "Employment crisis in the making?" *Biotech* June/July p17-18.

Arundel, A. & A. Rose (1999b) The diffusion of environmental biotechnology in Canada: adoption strategies and cost offsets". *Technovation* V19, 551-560.

Baldwin, J., J. Johnson. (1997). Differences in Strategies and Performance of Different Types of Innovators. Analytical Studies Branch – Research Paper Series #102. Statistics Canada. Ottawa.

Baldwin, J. (1997b). *Importance of R&D for Innovation in Small and Large Canadian Manufacturing Firms*. Analytical Studies Branch – Research Paper Series #107. Statistics Canada. Ottawa.

Baum, J., Brian Silverman (1998). *Alliances, Patents, and Competitive Dynamics in Canadian Biotechnology* in Proceedings of the Annual Conference of the Administrative Sciences Association of Canada.

Cecil, B. et al (1996). Patterns of strategic alliances among information technology firms in the United States, *Geograkiska Annaler* Series B 78(3), p129-146.

Dollinger, M., and Golden, P. (1992) Interorganizational and Collective Strategies In Small Firms: Environmental Effects and Performance. *Journal of Management* 18: 695-715.

Eliasson, G. (2000). The Industrial Potential of Biotechnology in *The Economic and Social Dynamics of Biotechnology*, J. de la Mothe & J. Niosi (eds.) Kluwer, Boston.

Fisher, L. (1996). *How Strategic Alliances Work in Biotech*. Booz-Allen & Hamilton. New York.

Gimba, G. (1994). *Strategic Alliances: When You Don't Want To Go It Alone*. ACG. Daytona Beach.

Hagedoorn, J. (1993) Understanding the Rationale of Strategic Technology Partnering: Interorganizational Modes of Co-operation and Sectoral Differences. *Strategic Management Journal*, 14: 371-385.

Hagedoorn, J. (1995) *Strategic Technology Partnering During the 1980s': Trends, Networks and Corporate Strategies in Non-Core Technologies*. Research Policy V. 24

Lebeskind, J., A. Oliver, L. Zucker, M. Brewer. (1995) *Social Networks, Learning and Flexibility: Sourcing Scientific Knowledge In New Biotechnology Firms*. National Bureau of Economic Research Inc. Cambridge.

Lerner, J., R. Merges. (1997). *The Control of Strategic Alliances: An Empirical Analysis of Biotechnology Collaborations*. National Bureau of Economic Research Inc. Cambridge.

Lerner, J. R. Merges (1998) The control of technology alliances: an empirical analysis of the biotechnology industry, in *The Journal of Industrial Economics* 45(2), p125-156.

Magun, S. (1996). *The Development of Strategic Alliances in Canadian International Economics*, Working Paper #13, Microeconomic Research and Statistical Analysis Branch, Industry Canada.

McNiven, Chuck (2001) *Biotechnology Use & Development Survey - 1999*. Statistics Canada Working Paper Series. Ottawa.

Niosi, J. (1996). Strategic technological collaboration in Canadian industry: towards a theory of flexible or collective innovation, in *Technological Collaboration: The Dynamics of Cooperation in Industrial Innovation,* R. Coombs et al (ed.) Edward Elgar Publishing. Brookfield VT.

Niosi. J. (2000) *Explaining Rapid Growth in Canadian Biotechnology Firms*, Research Paper #8, Science & Technology Redesign Project, Statistics Canada, Ottawa.

Niosi, J. (2000b). Strategy and Performance Factors Behind Rapid Growth In Canadian Biotechnology Firms, in *The Economic and Social Dynamics of Biotechnology*, J. de la Mothe & J. Niosi (eds.) Kluwer, Boston.

Rafiquzzaman, M., Whewell, L. (1998) *Recent Jumps In Patenting Activities: Comparative Innovative Performance Of Major Industrial Countries, Patterns And Explanations.* Working Paper 27, Industry Canada, Ottawa.

Read, C. (2000). *Survey of Intellectual Property Commercialization in the Higher Education Sector, 1999.* Working Paper Series, Statistics Canada, Ottawa.

Rojas, D. (1996). Finding strength in numbers, in *The Recorder.*

Senker, J., W. Faulkner (1996). Networks, tacit knowledge and innovation, in *Technological Collaboration: The Dynamics of Cooperation in Industrial Innovation,* R. Coombs et al (ed.) Edward Elgar Publishing. Brookfield VT.

Senker, J., M. Sharp. (1997). Organizational learning in cooperative alliances: some case studies in biotechnology, in *Technology Analysis & Strategic Management*, 9(1) p.35-51

The Economic & Social Dynamics of Biotechnology (2000) J. de la Mothe & J. Niosi (eds) Kluwer, Boston

Warda, J. (1999). *Measuring the Attractiveness of R&D Tax Incentives: Canada and Major Industrial Countries.* Working Paper Series, Statistics Canada, Ottawa.

Zucker, L., M. Darby, M. Brewer, Y. Peng. (1995). *Collaboration Structure and Information Dilemmas In Biotechnology: Organizational Boundaries As Trust Production.* National Bureau of Economic Research Inc. Cambridge.

Zucker, L., M. Darby, Y. Peng (1998) *Fundamentals Or Population Dynamics And The Geographic Distribution of U.S. Biotechnology Enterprises, 1976-1989.* National Bureau of Economic Research Inc. Cambridge.

Annex 1 - Questionnaire

Science, Innovation and Electronic Information Division

Biotechnology Use and Development Survey - 1999

Confidential when completed

Collected under the authority of the Statistics Act, Revised Statutes of Canada, 1985, c. S-19.
Completion of the questionnaire is a legal requirement under the Statistics Act.

Si vous préférez ce questionnaire en français, veuillez cocher ☐

Survey Purpose

Statistics Canada is undertaking this survey in support of the Canadian Biotechnology Strategy. The purpose is to produce information about firms engaged in biotechnology activities by addressing the following question. What are the characteristics and activities of firms that use or develop biotechnology as an important part of their firm's activity?

Biotechnology is a dynamic emerging sector of the Canadian economy and its impact has the potential to be felt through all parts of Canadian society. An accurate understanding of biotechnology requires comprehensive data. Information from this survey may be used by businesses for economic or market analysis, by trade associations to study industry performance, government departments and agencies to assist policy formation, and the academic community for research purposes. Statistics Canada will create a database combining survey responses with existing Statistics Canada data records. **An executive summary of the results will be sent to all respondents.**

Please report on Canadian biotechnology activities of your firm. Complete a separate questionnaire for each firm engaged in biotechnology activity in Canada.

Authority

Collected under the authority of the Statistics Act, Revised Statutes of Canada, Chapter S19. Completion of this questionnaire is a legal requirement under the Statistics Act.

Confidentiality

Statistics Canada is prohibited from publishing or releasing any statistics that would divulge information obtained from this survey that relates to any identifiable firm without the previous written consent of that firm. The data reported in this questionnaire will be treated in strict confidence, used for statistical purposes and released in aggregate form only. The confidentiality provisions of the Statistics Act are not affected by either the Access to Information Act or any other Legislation.

If you require assistance in the completion of the questionnaire or have any questions regarding the survey, please contact:

Claire Racine-Lebel
Science, Innovation and Electronic Information Division
Statistics Canada
Tunney's Pasture
Ottawa, Ontario
K1A 0T6
Phone: (613) 951-6309 (please call collect) - Fax: (613) 951-9920
e-mail: Claire.Racine-Lebel@statcan.ca

Please indicate the name of the person completing this form so we know who to contact should we have questions about this report.

Name	Title
Telephone Number ___ - ___ - ____ Fax Number ___ - ___ - ____	Email

5-4900-500 1 2000-01-13 STC/SAT-430-75177

1 Biotechnologies

1. Please review the following list of biotechnologies and check the applicable circle or circles.

	Biotechnologies	Currently Used in Operations 0	If currently using, do you use them for: Product/Process Research & Development 1	Current Production 2	Environmental Purposes 3	Number of Years in Use 4	If No: Do you plan to use within 3 years 5
	DNA Based						
1110	Gene Probes/DNA Markers	Yes / No					Yes / No
1120	Bio-Informatics	Yes / No					Yes / No
1130	Genomics/Pharmacogenetics	Yes / No					Yes / No
1140	Genetic Engineering/DNA Sequencing/Synthesis/Amplification	Yes / No					Yes / No
	Biochemistry/Immunochemistry						
1150	Vaccines/Immune Stimulants	Yes / No					Yes / No
1160	Drug Design & Delivery	Yes / No					Yes / No
1170	Diagnostic Tests/Antibodies	Yes / No					Yes / No
1180	Peptide/Protein Sequencing/ Synthesis	Yes / No					Yes / No
1190	Cell Receptors/Signalling/ Pheromones/Structural Biology	Yes / No					Yes / No
1200	Combinatorial Chemistry/ 3D Molecular Modelling	Yes / No					Yes / No
1210	Biomaterials	Yes / No					Yes / No
1220	Microbiology/Virology/Microbial Ecology	Yes / No					Yes / No
	Bioprocessing Based						
1230	Cell/Tissue/Embryo Culture Manipulation	Yes / No					Yes / No
1240	Extraction/Purification/Separation	Yes / No					Yes / No
1250	Fermentation/Bioprocessing/ Biotransformation/Natural Products Chemistry	Yes / No					Yes / No
	Environment						
1260	Bioleaching/Biopulping/Biobleaching/ Biodesulphurization	Yes / No					Yes / No
1270	Bioremediation/Biofiltration/ Phytoremediation	Yes / No					Yes / No
	Other *(please specify)*						
1280		Yes / No					Yes / No
1290		Yes / No					Yes / No

→ **If you use at least one of the biotechnologies in Question 1 go to Question 3.**

→ **If you don't use any of the biotechnologies listed in Question 1 go to Question 2.**

2 Barriers to Using Biotechnologies

2. Rate the following factors' influence on your firm's decision **not** to use biotechnology. Use the following scale where 1 is low importance and 5 is high importance. Indicate if not applicable to your firm.

		Importance					
		Low				High	Not Applicable
		1	2	3	4	5	0
	Lack of Financial Justification						
2100	Small market size	○	○	○	○	○	○
2110	High cost of equipment	○	○	○	○	○	○
2120	High cost to implement/integrate biotechnology	○	○	○	○	○	○
2130	Cost of capital	○	○	○	○	○	○
	Human Resources						
2140	Shortage of skilled or trained staff	○	○	○	○	○	○
2150	Worker resistance	○	○	○	○	○	○
2160	Increased labour costs	○	○	○	○	○	○
	External						
2170	Government regulations	○	○	○	○	○	○
2180	Public acceptance/perception of biotechnology	○	○	○	○	○	○
	Technology						
2190	Biotechnology not sufficiently developed	○	○	○	○	○	○
2200	Lack of external technical expertise/support	○	○	○	○	○	○
	Other (*please specify*)						
2210		○	○	○	○	○	○

If you are not using any biotechnology, please stop here.

Please return the questionnaire in the return prepaid envelope.

Thank you for your co-operation.

3 Information Sources on Biotechnology

3. Rate the importance of the following sources of information on biotechnology as used by your firm. Use the following scale where 1 is low importance and 5 is high importance. Indicate if not applicable to your firm.

	Sources of Information on Biotechnology	Importance Low 1	2	3	4	High 5	Not Applicable 0
3100	Internal resources/staff or parent/subsidiary firm	○	○	○	○	○	○
3110	Academic journals/trade publications	○	○	○	○	○	○
3120	Universities/colleges/private training institutes	○	○	○	○	○	○
3130	Federal government department/agency	○	○	○	○	○	○
3140	Personal contact with others (tacit knowledge)	○	○	○	○	○	○
3150	Other companies	○	○	○	○	○	○
3160	Provincial government department/agency	○	○	○	○	○	○
3170	Professional/industry associations	○	○	○	○	○	○
3180	Library/literature search	○	○	○	○	○	○
3190	Database retrieval services	○	○	○	○	○	○
3200	Conferences/workshops/trade shows	○	○	○	○	○	○
3210	Other (*please specify*)	○	○	○	○	○	○

4 Benefits from Using Biotechnology

4. a) Does your firm use biotechnology in its production or processing operations?

4100 ○ No → Go to Question 5

○ Yes

b) Rate the benefits from using biotechnologies in your firm's production or processing operations. Use the following scale where 1 is low importance and 5 is high importance. Indicate if not applicable to your firm.

	Benefit of Using Biotechnology	Importance Low 1	2	3	4	High 5	Not Applicable 0
	Productivity Improvement						
4110	Lower labour costs	○	○	○	○	○	○
4120	Lower capital costs	○	○	○	○	○	○
4130	Lower energy costs	○	○	○	○	○	○
	Product Improvement						
4140	Develop new products or processes	○	○	○	○	○	○
4150	Extend product range	○	○	○	○	○	○
4160	Improvement in product quality	○	○	○	○	○	○
	Plant Organization						
4170	Increase production flexibility	○	○	○	○	○	○
4180	Lower maintenance expenses	○	○	○	○	○	○
4190	Cleaner production/pollution reduction	○	○	○	○	○	○
	Market Performance						
4200	Improve market position	○	○	○	○	○	○
4210	Increase sales	○	○	○	○	○	○
4220	Reduced time to market/Faster delivery time	○	○	○	○	○	○
	Other (*please specify*)						
4230		○	○	○	○	○	○

5 Human Resources

For the purposes of this survey Employees are defined as those workers for whom you completed a Revenue Canada T4-Statement of Remuneration Paid Form for the 1999 tax year. Include working owner(s). Do not include students.

5 a) How many employees does your firm currently employ? 5100

b) How many employees have biotechnology-related responsibilities? 5110

c) In the table below provide the number of biotechnology employees. Class the employee by their primary area of responsibility. For example, a person working 60% of their time on biotechnology research would be counted once as mainly working in scientific/research direction.

	Position	Number Currently Employed		
		Working full-time on biotechnology (more than 50% of time) 1	Working part time on biotechnology (less than 50% of time) 2	Estimated number to be employed in biotechnology in 2002 3
	Biotechnology R&D Activities			
5120	Scientific/Research Direction			
5130	Technicians/Engineering			
5140	Regulatory/Clinical Affairs			
	Biotechnology Administration & Production			
5150	Production			
5160	Finance/Marketing			
5170	Management/Licensing/Administration			

d) Does your firm currently have unfilled full time biotechnology-related positions?

5180 ○ No → Go to Question 5 e)

○ Yes

	Position	If Yes, was the reason due to			
		Number of Unfilled Full-Time Positions 1	Lack of qualified candidates 2	Compensation required by qualified candidated too high 3	Other 4
	Biotechnology R&D Activities				
5190	Scientific/Research Direction		○ 1	○ 2	○ 3
5200	Technicians/Engineering		○	○	○
5210	Regulatory/Clinical Affairs		○	○	○
	Biotechnology Administration & Production				
5220	Production		○	○	○
5230	Finance/Marketing		○	○	○
5240	Management/Licensing/Administration		○	○	○

e) Does your firm employ (either paid or unpaid) post-secondary students in biotechnology-related activities? Include co-op placements, part-time, and full-time positions.

5250 ◯ No ⟶ Go to Question 5 f)

◯ Yes ⟶ What level of education? ⟶ 1 ◯ Technical/Trade/College
2 ◯ Undergraduate level
3 ◯ Graduate level

f) Does your firm contract out any of the following biotechnology-related activities?

	Biotechnology Activity	No 0	Yes	If yes, what is the value (in $000) of contracts in 1999? If more than one what is the total value? 1
5260	Research & Development	◯	◯ ⟶	$,000
5270	Regulatory/Clinical Affairs	◯	◯ ⟶	$,000
5280	Marketing/Distribution	◯	◯ ⟶	$,000
5290	Management/Licensing/Administration	◯	◯ ⟶	$,000

6 Recruiting Practices

6. Check any of the following methods used to fill biotechnology-related positions.

6000

1 ◯ Internet resources
2 ◯ University recruitment
3 ◯ Use under-qualified staff
4 ◯ Temporary/contract staff
5 ◯ Employment agencies
6 ◯ In-house training
7 ◯ Use over-qualified staff
8 ◯ Networking
9 ◯ Newspaper/journal ads
10 ◯ Professional associations
11 ◯ Other (*please specify*) _____

7. a) Did you attempt to hire biotechnology staff from outside Canada in 1999?

6100 ◯ No ⟶ Go to Question 7 c)

◯ Yes ⟶ From where? ⟶ 1 ◯ USA
2 ◯ Europe
3 ◯ Asia
4 ◯ Latin America
5 ◯ Other

b) Were you successful in hiring biotechnology staff from outside Canada?

6120 ◯ No

◯ Yes ⟶ How many biotechnology staff did you hire from outside Canada in 1999? 1 ☐

c) Did biotechnology personnel leave your firm in 1999?

6130 ◯ No

◯ Yes ⟶ How many? 1 ☐

7 Product/Process Development

8. a) Is your firm currently **developing** product that **requires** the use of biotechnologies?

7000 ◯ Yes

◯ No

8. b) Is your firm currently **developing** processes that **requires** the use of biotechnologies?

7110 ◯ Yes

◯ No

c) Does your firm consider biotechnology central to its activities?

7120 ◯ Yes

◯ No

Did you answer "Yes" to any part of Question 8?

7130 ◯ Yes ⟶ Go to Question 9

◯ No ⟶ Please stop here. Return the questionnaire in the prepaid return envelope. Thank you for your cooperation.

8 Biotechnology Products

9. Please provide the **number** of biotechnology products or processes your firm has at each stage of development.

	Biotechnology Sector	Number of biotechnology products/processes by development stage			
		Research & Development 0	Pre-clinical trials/ Confined field trials 1	Regulatory phase/ Unconfined release assessment 2	Approved/ On market/In production 3
	Human Health				
8110	**Diagnostics** (e.g. biosensors, immunodiagnostics, gene probes)				
8120	**Therapeutics** (e.g. vaccines, immune stimulants, biopharmaceuticals, rational drug design, drug delivery, combinatorial chemistry)				
	Agriculture Biotechnology				
8130	**Plant Biotechnology** (e.g. tissue culture, embryo-genesis, genetic markers, genetic engineering)				
8140	**Animal Biotechnology** (e.g. diagnostics, therapeutics, embryo transplantation, genetic markers, genetic engineering)				
8150	**Non-food Agriculture** (e.g. fuels, lubricants, commodity and fine chemical feedstocks, cosmetics)				
	Natural Resources				
8160	**Energy** (e.g. microbiologically enhanced petroleum recovery, industrial bioprocessing, biodesulphurization)				
8170	**Mining** (e.g. microbiologically enhanced mineral recovery, industrial bioprocessing, biodesulphurization)				
8180	**Forest Products** (e.g. biopulping, biobleaching, biopesticides, tree biotechnology, industrial bioprocessing)				
	Environment				
8190	**Air** (e.g. bioremediation, diagnostics, phytoremediation, biofiltration)				
8200	**Water** (e.g. biofiltration, diagnostics, bioremediation, phytoremediation)				
8210	**Soil** (e.g. biofiltration, diagnostics, bioremediation, phytoremediation)				

Biotechnology Products

	Biotechnology Sector	Number of biotechnology products/processes by development stage			
		Research & Development 0	Pre-clinical trials/ Confined field trials 1	Regulatory phase/ Unconfined release assessment 2	Approved/ On market/In production 3
	Aquaculture				
8220	Fish health, broodstock genetics, bioextraction				
	BioInformatics				
8230	**Genomics & molecular modelling** (e.g. DNA/RNA/ protein synthesising & databases for humans, plants, animals, and micro-organisms)				
8240	**Gene therapy** (e.g. gene identification, gene constructs, gene delivery)				
	Food Processing				
8250	**Bioprocessing** (e.g. using enzymes and bacteria culture)				
8260	**Functional Foods/Nutraceuticals** (e.g. probiotics, unsaturated fatty acids)				
	Other *(please specify)*				
8270					
8280					

9 Cooperative/Collaborative Arrangements

10. Was your firm involved in biotechnology-related **cooperative/collaborative arrangements** with other companies or organizations in 1999?
Cooperative and collaborative arrangements involve the active participation in projects by your company and other companies or organizations in order to develop and/or continue work on new or significantly improved biotechnology processes, products and/or services. Pure contracting-out is not regarded as collaboration.

9100 ○ No ⟶ Go to question 13

○ Yes ⟶ How many? ⟶ [ ] 1

11. Please indicate for which purposes. Check any that are applicable.

	Arrangement Purpose	
9110	To conduct research & development (R&D)/ Access to specialized inputs	○
9120	Regulatory affairs	○
9130	To access knowledge/skills/critical expertise	○
9140	Prototype development/production/manufacturing	○
9150	Access markets/distribution channels	○
9160	Access to capital	○
9170	Intellectual Property Protection	○
9180	Other (*please specify*)	○

12. Check collaboration/co-operation arrangements by each type and their geographic location.

	Partner Category	Canada 0	USA 1	Europe 2	Latin America 3	Asia 4
9190	A firm of smaller or equal size	○	○	○	○	○
9200	A larger firm	○	○	○	○	○
9210	Government department/agency	○	○	○	○	○
9220	University/Hospital/Research network	○	○	○	○	○
9230	Other (*please specify*)	○	○	○	○	○

13. Would you describe your firm as a 'spin-off'?
A Spin-off is defined as a new firm created to transfer and commercialize inventions and technology developed in universities, firms or laboratories.

9240 ○ No ⟶ Go to Question 14

○ Yes ⟶ Was your firm a spin-off from; ⟶
1 ○ University/hospital
2 ○ Another company
3 ○ Government agency/lab
4 ○ Other (*please specify*)

10 Obstacles to Biotechnology Commercialization

14. Rate the following **obstacles to advancement of biotechnology commercialization** activities in your firm.
Use the following scale where 1 is low importance and 5 is high importance. Indicate if not applicable to your firm.

		Importance Low 1	2	3	4	High 5	Not Applicable 0
	Inputs						
10100	Access to capital	○	○	○	○	○	○
10110	Access to technology/information	○	○	○	○	○	○
10120	Access to human resources	○	○	○	○	○	○
	Markets						
10130	Domestic market too small	○	○	○	○	○	○
10140	Lack of access to international markets	○	○	○	○	○	○
10150	Transportation regulations on biotechnology	○	○	○	○	○	○
10160	Lack of distribution & marketing channels	○	○	○	○	○	○
	Constraints						
10170	Public perception/acceptance	○	○	○	○	○	○
10180	Regulatory requirements	○	○	○	○	○	○
10190	Time/cost	○	○	○	○	○	○
10200	Patent rights held by others	○	○	○	○	○	○
10210	Lack of patent protection for plants	○	○	○	○	○	○
10220	Lack of patent protection for animals	○	○	○	○	○	○
10230	Lack of patent protection for human components (e.g., organs, tissues)	○	○	○	○	○	○
10240	**Other** (*please specify*)	○	○	○	○	○	○

11 Patents

15. a) How many patents and/or pending patents does your firm currently have in each region. (Indicate '0' if none).

		Geographic Location					
		None 5	Canada 0	USA 1	Europe 2	Latin America 3	Asia 4
11100	Existing patents						
11110	Pending patents						

b) Please indicate the number of **patent applications** your company submitted to the following Patent Offices. (Indicate '0' if none)

	Patent Office/Year	1998 0	1999 1
11120			
11130	Canadian Intellectual Property Office (CIPO)		
11140	United States Patent & Trademark Office (USPTO)		
11150	European Patent Office (EPO)		
11160	Other (*please specify*)		

c) Please indicate the number of applications for **plant breeders' rights** your company submitted. (Indicate '0' if none)

	Patent Office/Year	1998 0	1999 1
11170	Canadian Plant Breeders' Rights Office		
11180	Plant Variety Protection Office, USDA		
11190	Community Plant Variety Office, EU		
11120	Other (*please specify*)		

12 Intellectual Property

16. During the last two years, 1998-1999 did your firm **grant the right to use intellectual property** to another firm or did your firm **acquire the right to use intellectual property** from another firm?

12100 ◯ No ⟶ Go to Question 17

◯ Yes ⟶ Please indicate the type and direction of such intellectual property transfer.

	Intellectual Property	Granted Rights to Canadian Firms 0		Granted Rights to Foreign Firms 1		Acquired Rights from Canadian Firms 2		Acquired Rights from Foreign Firms 3	
		Yes	No	Yes	No	Yes	No	Yes	No
12110	Trade Secrets/Licensing Agreements	◯	◯	◯	◯	◯	◯	◯	◯
12120	Patents	◯	◯	◯	◯	◯	◯	◯	◯
12130	Plant breeders' rights	◯	◯	◯	◯	◯	◯	◯	◯

13 Revenues, Expenditures & Trade

17. Please provide financial details in the following table. Please report for fiscal years and in thousands of dollars ($,000's). Indicate "0" if none

		Please provide details in $,000's for the years		What is your forecast for 2002
		1998 (0)	1999 (1)	2002 (2)
13100	Total Firm Sales/Revenue	$,000	$,000	$,000
13110	% of Total Sales/Revenue From Biotechnology	%	%	%
13120	Total R&D Spending	$,000	$,000	$,000
13130	% of R&D Spending on Biotechnology R&D	%	%	%
13140	Total Exports (including licensing agreements)	$,000	$,000	$,000
13150	% of Exports from Biotechnology	%	%	%
13160	Total Imports	$,000	$,000	$,000
13170	% of Imports from Biotechnology	%	%	%

18. If your firm **exported** biotechnologies, what percentage (%) of biotechnology ***exports*** went to the following geographic locations in 1999? Include licensing agreements. What is your forecasted distribution for 2002?

	Year	Geographic Location				
		Canada (0)	USA (1)	Europe (2)	Latin America (3)	Asia (4)
13180	1999					
13190	Forecast for 2002					

19. If your firm **imported** biotechnologies, what percentage (%) of biotechnology ***imports*** came from the following geographic locations in 1999? Include licensing agreements. What is your forecasted distribution for 2002?

	Year	Geographic Location				
		Canada (0)	USA (1)	Europe (2)	Latin America (3)	Asia (4)
13200	1999					
13210	Forcast for 2002					

20. a) Did your firm attempt to raise capital for biotechnology in fiscal year 1999?

13220 ○ No ⟶ Go to Question 20 c)

○ Yes

b) Were you successful in raising capital?

13230 ○ No ⟶ Go to Question 20 c)

○ Yes ⟶ How much did you raise? (in thousands) ⟶ $,000

Indicate the sources of capital and the percentage (%) of total capital that source provided in 1999.

	Source	% of Total Capital
13240	Angel investors/family/friends	
13250	Government loans/grants/incentives	
13260	Venture Capital funds	
13270	Conventional sources (i.e. banks)	
13280	Initial Public Offering (IPO)	
13290	Collaborative alliance	
13300	Other *(please specify)*	
	TOTAL	100%

20. c) Does your firm plan to raise capital in 2002?

13310 ◯ No ⟶ Go to Question 21

◯ Yes ⟶ How much do you plan to raise in 2002? ⟶
1 ◯ Less than $500,000
2 ◯ $500,000 to $5,000,000
3 ◯ More than $5,000,000

21. In the past 5 years did your firm apply for the tax benefit for biotechnology related activities under the R&D (SRED) tax program?

13320 ◯ No ⟶ Why? ⟶
1 ◯ Complexity of application process
2 ◯ Uncertainty of eligibility
3 ◯ Did not meet eligibility requirements
4 ◯ Other (*please specify*) _____

◯ Yes

22. Does your firm use the Internet?

13330 ◯ No ⟶ Go to Question 23

◯ Yes ⟶ Indicate for what purposes your firm uses the Internet.
(Check any that are applicable.)

1 ◯ Sharing research & development
2 ◯ Marketing/selling
3 ◯ Purchasing goods and services
4 ◯ Accessing databases/information sources
5 ◯ E-commerce
6 ◯ Human resource search
7 ◯ Public relations
8 ◯ General communication
9 ◯ Other (*please specify*) _____

23. Which of the following strategies did your firm use in 1999?
(Check any that are applicable)

13400
1 ◯ Refocused product development
2 ◯ Downsized
3 ◯ Increased size
4 ◯ Entered product trials
5 ◯ Launched new product
6 ◯ Acquired a company
7 ◯ Out-source production
8 ◯ Licensed in technology
9 ◯ Licensed out technology
10 ◯ Merged with other company
11 ◯ Formed a joint venture
12 ◯ Expanded into foreign markets
13 ◯ No change
14 ◯ Other (*please specify*)

Comments

14100
If you have any comments regarding this survey, please provide them in the space below.

Thank you for your co-operation

Please return the questionnaire in the return prepaid envelope.

How to Order Catalogued Publications

These and other Statistics Canada publications may be purchased from local authorized agents and other community bookstores, through the local Statistics Canada offices, or by mail order to:

Statistics Canada
Dissemination Division
Circulation Management
120 Parkdale Avenue
Ottawa, Ontario
K1A 0T6

Telephone: 1(613)951-7277
National toll free order line: 1-800-700-1033
Fax number: 1-(613)951-1584 or 1-800-889-9734
Toronto Credit Card only (416)973-8018
Internet: order@statcan.ca

CATALOGUED PUBLICATIONS

Statistical Publication

88-202-XPB Industrial Research and Development, 2000 Intentions (with 1999 preliminary estimates and 1998 actual expenditures)

88-204-XIB Federal Scientific Activities, 2000-2001[e] (annual)

88-001-XIB Science Statistics (monthly)

Volume 24

No. 1 Federal Government Personnel Engaged in Scientific and Technological (S&T) Activities, 1990-1991 to 1999-2000[e]

No. 2 Biotechnology Research and Development (R&D) in Canadian Industry, 1997

No. 3 Industrial Research and Development, 1996 to 2000

No. 4 The Provincial Research Organizations, 1998

No. 5 Federal Government Expenditures on Scientific Activities, 2000-2001[e]

No. 6 Total Spending on Research and Development in Canada, 1989 to 2000[e], and Provinces, 1989 to 1998

No. 7 Estimation of Research and Development Expenditures in the Higher Education Sector, 1998-99

No. 8 Research and Development (R&D) Expenditures of Private Non-Profit (PNP) Organizations, 1999

Volume 25

No. 1 Distribution of Federal Expenditures on Science and Technology, by Province and Territories, 1998-99

No. 2 Estimates of Total Spending on Research and Development in the Health Field in Canada, 1988 to 2000[e]

No. 3 Biotechnology Scientific Activities in Selected Federal Government Departments and Agencies, 1999-2000

No. 4 Biotechnology Research and Development (R&D) in Canadian Industry, 1998

No. 5 Research and Development (R&D) Personnel in Canada, 1990 to 1999[e]

No. 6 Industrial Research and Development, 1997 to 2001

WORKING PAPERS - 1998

These working papers are available from the Science and Innovation Surveys Section of Statistics Canada, please contact:

Science and Innovation Surveys Section
Science, Innovation and Electronic Information Division
Statistics Canada
Ottawa, Ontario
K1A 0T6
Internet: http://www.statcan.ca/english/research/scilist.htm
Tel: (613) 951-6309

ST-98-01 A Compendium of Science and Technology Statistics, February 1998

ST-98-02 Exports and Related Employment in Canadian Industries, February 1998

ST-98-03 Job Creation, Job Destruction and Job Reallocation in the Canadian Economy, February 1998

ST-98-04 A Dynamic Analysis of the Flows of Canadian Science and Technology Graduates into the Labour Market, February 1998

ST-98-05 Biotechnology Use by Canadian Industry – 1996, March 1998

ST-98-06 An Overview of Statistical Indicators of Regional Innovation in Canada: A Provincial Comparison, March 1998

ST-98-07 Federal Government Payments to Industry 1992-93, 1994-95 and 1995-96, September 1998

ST-98-08 Bibliometric Analysis of Scientific and Technological Research: A User's Guide to the Methodology, September 1998

ST-98-09 Federal Government Expenditures and Personnel on Activities in the Natural and Social Sciences, 1989-90 to 1998-99[e], September 1998

ST-98-10 Knowledge Flows in Canada as Measured by Bibliometrics, October 1998

ST-98-11 Estimates of Canadian Research and Development Expenditures (GERD), Canada, 1987 to 1998[e], and by Province 1987 to 1996, October 1998

ST-98-12 Estimation of Research and Development Expenditures in the Higher Education Sector, 1996-97, November 1998

WORKING PAPERS - 1999

ST-99-01 Survey of Intellectual Property Commercialization in the Higher Education Sector, 1998, February 1999

ST-99-02 Provincial Distribution of Federal Expenditures and Personnel on Science and Technology, 1988-89 to 1996-97, June 1999

ST-99-03 An Analysis of Science and Technology Workers: Deployment in the Canadian Economy, June 1999

ST-99-04 Estimates of Gross Expenditures on Research and Development in the Health Field in Canada, 1970 to 1998[e], July 1999

ST-99-05 Technology Adoption in Canadian Manufacturing, 1998, August 1999

ST-99-06 A Reality Check to Defining E-Commerce, 1999, August 1999

ST-99-07 Scientific and Technological Activities of Provincial Governments, 1990-1991 to 1998-1999[e], August 1999

ST-99-08 Estimates of Canadian Research and Development Expenditures (GERD), Canada, 1988 to 1999[e], and by Province, 1988 to 1997, November 1999

ST-99-09 Estimation of Research and Development Expenditures in the Higher Education Sector, 1997-98

ST-99-10 Measuring the Attractiveness of R&D Tax Incentives: Canada and Major Industrial Countries, December 1999

WORKING PAPERS - 2000

ST-00-01 Survey of Intellectual Property Commercialization in the Higher Education Sector, 1999
April 2000

ST-00-02 Federal Government Expenditures and Personnel in the Natural and Social Sciences, 1990-91 to 1999-2000^{e}, July 2000

ST-00-03 A Framework for Enhanced Estimations of Higher Education and Health R&D Expenditures, by Mireille Brochu, July 2000

ST-00-04 Information and Communications Technologies and Electronic Commerce in Canadian Industry, 1999, November 2000

WORKING PAPERS - 2001

ST-01-01 Estimates of Canadian Research and Development Expenditures (GERD), Canada, 1989 to 2000^{e}, and by Province 1989 to 1998, January 2001

ST-01-02 Estimation of Research and Development Expenditures in the Higher Education Sector, 1998-99, January 2001

ST-01-03 Innovation, Advanced Technologies and Practices in the Construction and Related Industries: Provincial Estimates, 1999, January 2001

ST-01-04 Innovation, Advanced Technologies and Practices in the Construction and Related Industries: National Estimates, 1999, February 2001

ST-01-05 Provincial Distribution of Federal Expenditures and Personnel on Science and Technology 1990-91 to 1998-99, February 2001

ST-01-06 Estimates of Total Expenditures on Research and Development in the Health Field in Canada, 1988 to 2000^{e}, March 2001

ST-01-07 Biotechnology Use and Development, 1999, March 2001

ST-01-08 Federal Government Expenditures and Personnel in the Natural and Social Sciences, 1991-92 to 2000-2001^{e}, April 2001

ST-01-09 Estimates of Research and Development Personnel in Canada, 1979 to 1999^{e}, June 2001

ST-01-10 Innovation in Canadian Manufacturing: National Estimates, 1999, June 2001

RESEARCH PAPERS – 1996-2001

No. 1	The State of Science and Technology Indicators in the OECD Countries, by Benoit Godin, August 1996
No. 2	Knowledge as a Capacity for Action, by Nico Stehr, June 1996
No. 3	Linking Outcomes for Workers to Changes in Workplace Practices: An Experimental Canadian Workplace and Employee Survey, by Garnett Picot and Ted Wannell, June 1996
No. 4	Are the Costs and Benefits of Health Research Measurable?, by M.B. Wilk, February 1997
No. 5	Technology and Economic Growth: A Survey, by Petr Hanel and Jorge Niosi, April 1998
No. 6	Diffusion of Biotechnologies in Canada, by Anthony Arundel, February 1999
No. 7	Barriers to Innovation in Services Industries in Canada, by Pierre Mohnen and Julio Rosa, November 1999
No. 8	Explaining Rapid Growth in Canadian Biotechnology Firms, by Jorge Niosi, August 2000
No. 9	Internationally Comparable Indicators on Biotechnology: A Stocktaking, a Proposal for Work and Supporting Material, by W. Pattinson, B. Van Beuzekom and A. Wyckoff, January 2001
No. 10	Analysis of the Survey on Innovation, Advanced Technologies and Practices in the Construction and Related Industries, 1999, by George Seaden, Michael Guolla, Jérôme Doutriaux and John Nash, January 2001
No. 11	Capacity to Innovate, Innovation and Impact: The Canadian Engineering Services Industry, by Daood Hamdani, March 2001